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The Oriental Fruit Fly from the Mainland Viewpoint

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In view of the fact that the melon fly and the Mediterranean fruit fly, which have been present in the Hawaiian Islands for nearly half a century, have never become established on the Pacific Coast, it might be reasonable to assume that continuation of the safeguards set up to protect mainland agriculture against their entry, would give similar protection against the introduction of Oriental fruit fly which has only recently made its appearance in that area. However, there are certain factors involved in the latter situation which give cause for concern on the part of mainland agriculturists.

Since its recent appearance in the Hawaiian Islands the Oriental fruit fly has increased to almost unbelievable numbers. Its behavior following its introduction represents a typical example of a species newly introduced into a very favorable habitat without any of the natural factors that may have held it in check in its native home. In the wild guava, which grows profusely over all of the Islands, it has found a very favorable host. This, together with exceptionally favorable climatic conditions, a high biotic potential, and the apparent absence of any parasites or predators in its new home, have permitted it to reach and maintain epidemic numbers which present a constant threat of introduction to the mainland never present with respect to the other two species.

In the islands the Oriental fruit fly has proven a more dominant and aggressive species than either the melon fly or Mediterranean fruit fly. In fact, in the short time it has been known in the Islands, it has not only replaced the latter at the lower elevations but infests a wider range of hosts to a greater degree.

Over 100 varieties of fruits and vegetables are included among its known hosts ranging from macadamia nuts to strawberries. Recorded hosts include such economic crops of importance on the mainland as grapefruit, oranges, lemons, avocados, figs, peaches, plums, cherries, apples, walnuts, olives, persimmons, tomatoes and watermelons. It even finds cotton bolls acceptable and has been reared through a complete life cycle in the blooms of vanda orchids. Fruits of the common ornamental date palm serve as an excellent host. In fact, it would appear that any above-ground, fleshy fruit, vegetable or seed is a potential host.

It is possible that this wide range of hosts may be entirely due to "population pressure" of the pest and that if it were possible to eliminate the wild host, which has made such populations possible, the number of actual or primary hosts might be materially reduced. It is certain, however, that the primary hosts would still include the economic crops named above. There is support for the population pressure idea in the comment of Kenneth Maehler, Quarantine Officer for the Pacific Trust Territory, to the effect that in Guam in the absence of any extensive reservoir of wild hosts, mango is seldom infested beyond 4 to 6 per cent. In the Islands, in the presence of abnormal numbers of the fly, this host suffers nearly 100 per cent from attack.

Normally the adult female prefers to oviposit only in mature or near mature fruit and larval development may be completed even in fallen fruit. Major fruit losses result from this type of infestation and the picking up and destroying of fallen fruits may materially reduce any build-up in number of flies. However, under pressure, the adults will oviposit in any fleshy plant tissue which may account for their attack on gardenia, ginger and

PACIFIC SLOPE BRANCH PROGRAM.

vanda orchid blooms. They may oviposit in the stems of some hosts causing splitting and ultimate death of the plant beyond the point of attack. They are capable of ovipositing and do oviposit, extensively in young, hard, green fruits such as macadamia nuts, walnuts and young coconuts. Immature citrus fruits and avocados particularly are the subject of such attack. While the eggs deposited under such conditions may be extruded or crushed by the developing tissue, or if they do hatch, the larvae fail to survive, the punctures themselves may so mar or disfigure the fruit as to destroy its later commercial value. In the case of grapefruit, gum may be exuded copiously from each puncture accompanied by a gradually enlarging discolored surface area which will extend down through the rag into the flesh. In the case of avocados a latex is exuded which forms a conspicuous white crystalline deposit on the outer skin with a blackened area developing around each puncture. Further loss of fruit often results from the early entrance of rot organisms through such punctures while the fruit is still on the tree.

Preliminary ecological studies by Hawaiian entomologists indicate that the Oriental fruit fly is a very plastic species and may have the ability of adapting itself to a rather wide range of climatic conditions. While it would appear to meet optimum conditions in the warm equable climate at sea level in the islands where it can complete its life cycle in as little as 21 days, at 6500 feet studies have demonstrated its ability to complete its cycle during periods when the temperature has dropped repeatedly to 32°F. and occasionally as low as 28°F. It apparently has no hibernation stage but under the conditions cited materially extends the period of development of each stage and may require as long as 69 days to complete its cycle.

In recent tests on Hawaii 45 out of 50 adults held in cages at the high elevations were still alive at the end of 47 days. Earlier workers in Formosa found that adults might live in the presence of food as long as 4 months. These factors suggest an ability to survive under somewhat adverse conditions.

It is possible that, given the opportunity, the Oriental fruit fly could not only survive but could reach damaging numbers along the coast of California from San Francisco south to San Diego, including most of southern California; in the Rio Grande Valley on the southern tip of Texas; and in the lower half of Florida. A much wider area including all of the southern and southwestern states outside of the desert regions might be acceptable to its survival or could be seriously affected by populations migrating during the summer months from more favorable locations.

In southern California the Valencia orange, which is normally held on the trees throughout the summer months, often overlapping the maturing navel crop might easily serve as a host reservoir comparable with wild guava in the islands. Lemons also might serve as a round-the-year host, being present in volume throughout the year, through normally harvested before reaching a maturity attractive to the fly. Cotton also might prove to be an equally effective host reservoir throughout the southern states as well as in the great central valleys of California, permitting the development of high populations of flies which could be seriously damaging to nearby orchard or row crops. There is also a continuity in the fruiting seasons of commonly used ornamentals and native shrubs and trees which may later be found to be acceptable hosts and aid in the build-up or survival of the fly under mainland conditions.

From the island standpoint the problem would appear to be one of learning to live with the fly under conditions which preclude its ever being controlled directly by chemical measures until some means of eliminating its wild hosts is found. In the islands the best promise of control would seem to lie in the use of biological methods, already receiving major attention. This approach, however, would be of little immediate value to the mainland in attempting the eradication of an incipient infestation or early control of any established infestation.

Limited tests by investigators in the islands show DDT to be the most effective and most readily available of the newer organic chemicals in controlling this new species of fruit fly, but in the absence of any material residual effect its use requires expensive repeated applications at short intervals. None of the older stand-

ard insecticides, such as pyrethrum, nicotine, cryolite or rotenone, normally toxic to such insects, seem to have been tried. However, the results of using such materials, even if effective as a contact spray or dust against the adults at the time of application, are almost immediately nullified in the islands by the influx of adults from adjacent wild hosts. Under these conditions it cannot be expected that island authorities will be of much immediate assistance in developing means of eradication or control which would be available for use on the mainland should the occasion arise.

From the mainland standpoint the problem is a national one and not that of any one individual state, and is recognized as a Federal responsibility. While California would appear to be the most vulnerable to introduction of the fly due to is round-the-clock contacts with the islands by plane and surface ships, it might not necessarily be the first state to be invaded. The Oriental fruit fly has been intercepted more than once at eastern seaports in infested fruits from the East Indies, so that entry into the country, if it occurs, need not necessarily be through the shortest channels.

At the present time quarantine safeguards, which would seem to have reached the limits of human ability, are imposed at origin on all planes moving from the islands to the mainland. There is, however, no present control over the carrying of untreated host fruits from the islands as stores or in passengers' possession on surface ships moving from Hawaii to mainland ports until they reach these ports. Nor are any quarantine safeguards imposed in the islands on foreign vessels moving to other countries in the western hemisphere. This makes it possible to bring infested fruit to our front door before restrictions are imposed, or to land it in a near by foreign country without restriction. Once established in another mainland country, particularly to the south of us, it might be only a matter of time before it spread naturally into the United States. Some attempt to eliminate this latter hazard might well be made through international agreements with the countries concerned. Treatment at origin should be made mandatory as a condition for moving host material directly to mainland ports.

The Federal Bureau of Entomology and Plant Quarantine can be expected to impose the same type of restriction on the movement of host fruits and vegetables from any mainland area in which the fly may appear as it now imposes against Hawaii. That would mean that all such fruits and vegetables would be permitted to move from any defined infested area only under approved federally supervised treatment. Such action could be more serious to many states, particularly if it involved volume crop movements at peak harvest, than would be the actual damage from the fly itself.

Treatments under which such movements might safely be made are still to be worked out with respect to most commodities though there is some background of experience in this field with respect to Mediterranean fruit fly and Mexican fruit fly in citrus fruits. In most cases, however, not only the method but the host tolerance to such method is still to be determined. Studies to this end should be accomplished sufficiently in advance to be immediately available should there be need.

The sudden placing of such restrictions on any area producing a volume of agricultural products for interstate shipment could seriously affect the economy of states dependent for their supplies on such areas.

While cognizant of its exposed position to the introduction and establishment of the fly and the economic impacts that would probably follow its finding within the state, California now has detection traps located in all areas within the state which have or have had direct contact with the Islands, either by plane or by surface ship, during the past few years. Such trapping is being conducted in the hope that any incipient infestation can be discovered in sufficient time to permit the application of eradication measures with some reasonable expectancy of success. Aside from host fruit removal and destruction, if deemed practical at the time, the chemical treatment to be used in any such situation is still to be worked out. The successful effort directed against eradication of Mediterranean fruit fly in Florida some 25 years ago gives encouragement to such an approach. It is, of course, understood that any program of trapping or eradication at the state level would

merely be a stop-gap measure until the proper Federal agency could exercise its authority and responsibility and further participation fitted into their plans.

The present major problems involved in this situation from the mainland viewpoint can be summarized as follows:

(1) Intensified world search for parasites and predators which may be effectively used in reducing the present population of flies in Hawaii, thus proportionately reducing the hazard of early spread to the mainland, with serious consideration being given to their mass production and timed liberation.

(2) Intensified studies of the life history and behavior of the fly under climatic conditions comparable with the mainland to determine more accurately, in advance, its possible economic importance if established there.

(3) A careful study of the susceptibility to attack of fruits and vegetables common to the mainland but not found in Hawaii.

(4) Early development of chemical field treatments that would permit the effective eradication or control of any infestation which might be found on the mainland.

(5) The development of effective and practical methods of treating host fruits and vegetables and the determination of their tolerance to such treatments, which would permit their safe movement from infested to clean areas, should such action become necessary.

(6) The development of more effective lures and of an adequate program of trapping in suspected areas for the purpose of detecting any incipient infestation in time to permit the application of eradication measures with some reasonable expectancy of success.

(7) The formulation in advance of a program that would permit the orderly and safe movement of host fruits and vegetables from an infested area and accomplish eradication of any incipient infestation with a minimum of disturbance to the agricultural industry.

The seriousness of the situation is indicated by the fact that congress is giving favorable consideration to the appropriation of $400,000 annually in addition to the $50,000 included in existing appropriations for carrying out the needed research presented by these problems. The territorial government has already appropriated $380,000 for similar purposes over and above $80,000 specifically provided in the budget of the Territorial Board of Agriculture and Forestry, for Oriental fruit fly control. California has included in its current budget $200,000 for such use as might properly be made in cooperating in research studies with official agencies in Hawaii and with the U. S. Department of Agriculture. In addition, an emergency fund of $100,000 has been made available by the legislature for use in initiating eradication measures should the occasion arise.

The problems outlined above present a real challenge to the entomologists of the country if serious losses from the inadvertent introduction and establishment of the Oriental fruit fly on the mainland are to be avoided.

Investigations of Tick Repellents at Camp Bullis, Texas, 1948

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From laboratory screening tests that have been carried out at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine during recent years, a considerable number of compounds were selected which appeared to be of promise as tick repellents. Preliminary testing of a few compounds under field conditions was undertaken in 1943 and 1944, in cooperation with the Post Surgeon's office at Camp Bullis, Tex. (Smith and Gouck 1946). Studies of other new materials were conducted during 1947 at Camp Bullis and also in South Carolina in areas naturally infested with the lone star tick, *Amblyomma americanum* (L.) (King 1948). Data were obtained on effectiveness and durability of the ma-

[1] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, under funds allotted by the National Military Establishment.
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terials and on methods of testing. Field tests with several of the repellent materials at Camp Bullis during 1947 have also been reported by Brennan (1948).

In the spring of 1948 cooperative arrangements were made with the Brooke Army Medical Center, Fort Sam Houston, Tex.,[3] for more extensive testing of standard army uniforms treated with a group of selected repellents. For this project 25 enlisted men from the Demonstration Section, Headquarters Detachment, Medical Field Service School of the Medical Center, were assigned to wear the treated uniforms. Most of the men served throughout the testing period. The tests were conducted at Camp Bullis, where a heavy infestation of the lone star tick occurs. They were begun on April 20 and terminated on May 28.

The organic compounds originally screened as tick repellents (Smith and Burnett 1948) had previously shown a high degree of repellency or toxicity to mosquitoes, mites, or lice. The materials that appeared to be of promise were submitted to the U. S. Food and Drug Administration for pharmacological tests on laboratory mammals. Some of the materials produced toxic symptoms or skin irritation, some were indicated to be suitable for use directly on the skin as well as on clothing, and some appeared safe for use on the clothing but not on the skin. Those that showed definitely harmful effects were eliminated, and a considerable number of the others were not available in sufficient quantity for treatment of entire uniforms. Compounds available for the 1948 tests were first subjected to small-scale field tests at Bull's Island, S. C.,[4] and 19 of these compounds were selected for later tests at Camp Bullis. A few of the compounds caused skin irritation on some subjects, usually associated with sweating, and others have not been finally evaluated as to their suitability for unrestricted use on clothing.

METHODS.—The uniforms used in the tests were regulation two-piece army fatigues of herringbone twill and were impregnated at the rate of 2 grams of the test compound per square foot of cloth. Two formulations were employed to impregnate the uniforms—(1) acetone solutions, at the rate of 75 grams of repellent in 1,500 ml. of acetone to each uniform, and (2) positively charged (cationic) emulsions at the rate of 100 grams of repellent in water to make 3 gallons. The latter method is based upon the attraction of the negatively charged fibers of wet cloth for the positively charged dispersed phase of the emulsion. It was estimated that approximately 75 grams of the chemical was deposited as a residue in the treated garment, but the actual amount probably varied with the different repellents.

Three uniforms treated with acetone solutions of each compound were worn once a week for 3 weeks in tests referred to hereinafter as intermittent wear. Twelve compounds were put in test at the beginning of the study and the five most effective ones were continued in test for an additional 3 weeks. Tests with seven other compounds were started at the beginning of the second 3-week period. When sufficient quantities were available, three uniforms treated with acetone solution and three treated with emulsions were worn each day for five successive days, in tests referred to hereinafter as daily wear. The emulsion treatments were not tested further, but some of the most effective acetone treatments were tested for 1 to 3 additional weeks.

Subjects wearing the treated uniforms were exposed in tick-infested territory for 4 hours beginning about 9 a.m. The trousers were tucked into combat boots, and jackets were worn with the lower edge loose, outside the trouser tops. Pistol belts were usually worn over the jacket. After the 4-hour exposure the uniforms were left on for an additional 30 minutes to allow time for the ticks to attach to the subjects or to drop off or die, according to the effectiveness of the chemical. During exposure the subjects usually sat or lay on the ground, reading, sleeping or playing cards. All were cautioned not to brush or pick off the ticks. Every 30 to 60 minutes the men were moved to a different focus of infestation.

After the 30-minute waiting period the

[3] Grateful acknowledgment for helpful cooperation and assistance in the program is made to Major General J. M. Willis, Commanding General, Brooke Army Medical Center, Fort Sam Houston, Tex.; Brig. Gen. J. I. Martin, Commandant, and Col. J. L. Snyder, Assistant Commandant, Medical Field Service School; Col. Dwight M. Kuhns, Commanding Officer, Fourth Army Area Medical Laboratory; Col. T. C. Patton, Surgeon's Office, Fourth Army; Lt. Col. G. L. Orth, Director, Dept. of Preventive Medicine, and Lt. Col. D. C. Carle, Director, Dept. of Training, Medical Field Service School; to W. V. King, in charge, and D. Kelsey, Orlando, Fla., Laboratory, and R. C. Bushland, Kerrville, Tex., Laboratory, U. S. Bureau of Entomology and Plant Quarantine.

[4] Moses M. Cole and Carroll N. Smith. Unpublished manuscript.

uniforms were removed and all ticks were picked off the body and clothing by the subjects, under the supervision of the writers. The ticks were collected on cellulose tape and counted later. Separate records of attached and unattached ticks were kept, but as the number of attachments proved to be very small both counts were combined in calculating the effectiveness of the repellent materials. Only nymphs and adults were involved in the tests, since few larvae were encountered at this season of the year.

The uniforms were issued at random to the subjects, except that no uniform was issued to the same man in successive tests. Two untreated uniforms were worn as checks each day, but the subjects were not informed as to which these were. Replicate tests were usually not made on the same day or in the same location.

The results of the tests were expressed as per cent repellency derived from the formula $100(N-T) \div N$, in which N is the number on the check (in this case the average of two untreated uniforms) and T the number on the treated uniform. A total of 25 ticks on the check was established arbitrarily as the minimum required for suitable testing conditions, and when the average on the checks dropped below 25, as occasionally happened early in the season, the tests for that day were not included in the evaluation of effectiveness.

RESULTS.—The results of the intermittent-wear tests with 19 compounds are summarized in table 1, the percentage of repellency shown being the average for three uniforms worn on different days. All the treatments gave more than 85 per cent repellency during the first tests and all except two gave more than 90 per cent. Thirteen of the compounds had an average of 96 per cent or higher during the first 3 weeks. Five of them were continued in test for an additional 3 weeeks—namely, *N*-butylacetanilide (No. 1), cyclohexanepropionic acid (No. 3), 2-[-(2-ethylhexyloxy)ethoxy] ethanol (No. 6), hexyl mandelate (No.10), and *Indalone* (No. 12). Limitations of time and personnel prevented additional testing of the other eight of the more effective compounds. The two least effective materials were dimethyl carbate (No. 15) and diphenylamine (No. 5). The latter also caused irritation to the skin of several subjects and was dropped from testing after the second week.

The results of the daily-wear tests with 14 compounds are summarized in table 2.

Table 1.—Repellency of impregnated uniforms to the lone star tick. Average of 3 replications.

REPELLENT	PER CENT REPELLENCY AT INDICATED INTERVALS AFTER TREATMENT (WEEKS)					
	1	2	3	4	5	6
Uniforms treated April 16, 1948						
1. Acetanilide, *N*-butyl-[1]	100	100	98	98	98	88
2. Acetic acid, thiocyano-, fenchyl and isobornyl esters (*Thanite*)[1]	95	98	95	—	—	—
3. Cyclohexanepropionic acid[1]	99	98	98	94	97	82
4. Cyclohexanol, 2-phenyl-	98	99	69	—	—	—
5. Diphenylamine[1]	86	85	—	—	—	—
6. Ethanol, 2-[2-(2-ethylhexyloxy)-ethoxy][1]	100	100	99	88	86	78
7. Ethanol, 2-(2-hexyloxyethoxy)-	99	97	61	—	—	—
8. Hendecanal, 2-methyl-	100	96	98	—	—	—
9. Isobutyric acid, 2-phenoxyethyl ester	96	92	60	—	—	—
10. Mandelic acid, hexyl ester	100	99	99	99	99	93
11. Phthalic acid, diethyl ester	97	94	98	—	—	—
12. 1,2*H*-Pyran-6-carboxylic acid, 3,4-dihydro-2,2-dimethyl-4-oxo-, butyl ester (*Indalone*)	94	98	99	94	87	91
Uniforms treated May 4, 1948						
13. Acetamide, *N*-amyl-alpha-butoxy-	99	99	95	—	—	—
14. Acetanilide, *N*-ethyl-	92	75	83	—	—	—
15. Bicyclo[2.2.1]-5-heptene-2,3-dicarboxylic acid, *cis*- dimethyl ester (dimethyl carbate)	88	88	74			
16. Dodecanal	93	99	98	—	—	—
17. Hendecenoic acid	99	100	99	—	—	—
18. 4-Morpholineacetic acid, isobornyl ester	98	100	95	—	—	—
19. 2-Propanol, 1-[1-(3,3,5-trimethyl-cyclohexyloxy)-2-propoxy]-[1]	99	96	99	—	—	—

[1] Caused irritation to the skin of some subjects in these or other tests.

In these tests comparisons were also made of impregnations with acetone solutions and emulsions with 11 of the compounds. Paired tests were conducted on five consecutive days and the uniforms were worn for a total of 5 hours per day. In most cases there were two or three replications of each treatment. Acetone solutions gave slightly better results than the emulsions with five of the compounds (Nos. 4, 6, 8, 11, and 12), distinctly better results with two (Nos. 7 and 15), and approximately equal results with three (Nos. 1, 2, and 3). With diphenylamine (No. 5) the general average for the acetone treatments was lower than that for the emulsion treatments, but the results were extremely variable by each method. The two compounds that gave distinctly better results as solutions were ones that formed unstable emulsions.

From the tests with acetone impregnations in this series, only three of the compounds—diphenylamine (No. 5), 2-phenylcyclohexanol (No. 4), and 2-phenoxyethyl isobutyrate (No. 9)—failed to maintain a high repellency through the first 5 days of wear. Seven of the other materials were continued in test over periods of 2 to 6 weeks. A slight decline in effectiveness was observed, but an average repellency of about 90 per cent or higher was generally maintained. With the four compounds in the longest tests there was at least one occasion when the daily average dropped below 90 per cent. In each case, however, subsequent tests again showed a high degree of repellency. For example, in 19 tests the average repellency was below 90 per cent twice with *N*-butylacetanilide (No. 1), twice with cyclohexanepropionic acid (No. 3), four times with 2-[2-(2-ethylhexyloxy)ethoxy] ethanol (No. 6), and three times (in 14 tests) with *Indalone* (No. 12).

A comparison of the two series of tests shows that the aging of the treatments appeared to have a greater effect on duration of repellency than the amount of wear. Even in the longest tests there was little difference in effectiveness of the same compounds during the 6th week, whether they had been subjected to a total of more than 75 hours of wear or only 25 hours.

Although the proportion of ticks that

Table 2.—Effectiveness in daily-wear tests of uniforms treated with emulsions and acetone solutions of tick repellents. Average of 2 or 3 replications.

Compound	Type of Impregnation	Per Cent Repellency in Consecutive Tests				
		1	2	3	4	5
1. Acetanilide, *N*-butyl-	Solution	100	98	99	100	99
	Emulsion	99	100	100	99	99
2. Acetic acid, thiocyano-, fenchyl and isobornyl esters (*Thanite*)	Solution	96	91	92	93[1]	92
	Emulsion	87	93	94	—	97
3. Cyclohexanepropionic acid	Solution	99.7	98	89	99	97
	Emulsion	100[1]	—	—	97[1]	97[1]
4. Cyclohexanol, 2-phenyl-	Solution	99	95	97	89	87
	Emulsion	97	92	90	87	77
5. Diphenylamine	Solution	65	97	97	86	46[1]
	Emulsion	82	68[1]	100[1]	84	84[1]
6. Ethanol, 2-[2-(2-ethylhexyloxy)-ethoxy]-	Solution	100	99	99	100	97
	Emulsion	98	99	99	95	91
7. Ethanol, 2-(2-hexyloxyethoxy)-	Solution	97	96	98	92	91
	Emulsion	88	73[1]	73[1]	88	76
8. Hendecanal, 2-methyl-	Solution	99	98	99	97	99
	Emulsion	97	89	88	84[1]	93
9. Isobutyric acid, 2-phenoxyethyl ester	Solution	99	100	96	90	67
10. Mandelic acid, hexyl ester	Solution	99	98	97	95	97
11. Phthalic acid, diethyl ester	Solution	93	93[1]	98[1]	96	90
	Emulsion	96[1]	—	—	72[1]	100[1]
12. 1,2*H*-Pyran-6-carboxylic acid, 3,4-dihydro-2,2-dimethyl-4-oxo-, butyl ester (*Indalone*)	Solution	100	97	99	96	98
	Emulsion	95	95	96	92	96
14. Acetanilide, *N*-ethyl-	Solution	98	98	96	94	96
15. Bicyclo[2.2.1]-5-heptene-2,3-dicarboxylic acid, *cis*-dimethyl ester (dimethyl carbate)	Solution	99	97	98	89	95
	Emulsion	84	88	84	70	75[1]

[1] Results of 1 test only.

attached to the subjects was unexpectedly small, the total attachments in all tests provide a comparison of the effectiveness of the compounds in preventing bites, and also of their repellency to nymphs and adults. The combined totals, as given in table 3, show that adults were repelled somewhat less than nymphs and that effectiveness on the basis of attachments was lower than that indicated by the number of unattached ticks. The repellency for all treatments (including the poorest), as indicated by the average number of ticks per test, was 94 per cent.

ethyl phthalate were highly effective and have been indicated as safe for use on clothing at the rate employed. The first three, however, were reported to be unsafe for use directly on the skin. Other highly effective compounds were *Thanite*, cyclohexanepropionic acid, 2-methylhendecanal, *N*-amyl-alpha-butoxyacetamide, dodecanal, isobornyl 4-morpholineacetate, and 1-[1-(3,3,5-trimethylcyclohexyloxy)-2-propoxy]-2-propanol. Six of the materials—*N*-butylacetanilide, *Thanite*, cyclohexanepropionic acid, diphenylamine, 2-[2-(2-ethylhexyloxy)ethoxy] etha-

Table 3.—Average tick infestations found on subjects wearing treated and untreated uniforms.

Stage	Treated: Number		Untreated: Number		Per Cent Repellency	
	Unattached	Attached	Unattached	Attached	Unattached	Attached
Nymphs	4.0	0.2	71.9	1.7	95	88
Males	1.0	.06	12.2	0.4	92	85
Females	0.7	.03	6.8	.2	90	85
Total	5.99		93.2		94	
Number of tests	645		55		—	

SUMMARY.—Field tests with tick repellents were conducted at Camp Bullis, Tex., during April and May 1948. The repellents were applied to standard army fatigue uniforms, which were worn by a group of 25 enlisted men in areas heavily infested with the lone star tick, *Amblyomma americanum* (L.). The 19 materials tested were selected from ones that had shown promise in previous laboratory and field tests. Most of them proved to have a high degree of repellency, averaging better than 90 per cent during the periods of tests, which varied from 3 to 6 weeks. *Indalone*, one of the more effective materials, is considered safe for use on both the skin and clothing *N*-Butylacetanilide, 2-[2-(2-ethylhexyloxy)ethoxy]ethanol, hendecenoic acid, hexyl mandelate, and dinol, and 1-[1-(3,3,5-trimethylcyclohexyloxy)-2-propoxy]-2-propanol — caused irritation to the skin of some subjects.

Impregnation of the uniforms with acetone solutions of the repellents gave slightly better results on the whole than impregnation with emulsions by a method of ionic exchange. Two of the compounds did not form satisfactory emulsions by this method.

The effectiveness of the treatments decreased somewhat with age, but the amount of wear to which the uniforms were subjected did not have a marked effect. Three compounds on uniforms that were worn and tested 19 times after treatment over a period of 6 weeks retained a high proportion of their original effectiveness at the end of the period.

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Studies of the Mode of Action of Parathion and Its Derivatives and Their Toxicity to Insects[1]

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The development of the insecticide parathion has been described by Schrader (1947). It is also apparent from his work that a considerable number of compounds related to parathion are highly toxic. However, the published insecticidal data on these materials is very fragmentary, and in some cases of doubtful character due to the unfortunate destruction of many original records. It is the purpose of this paper to present data on the relative toxicities of parathion and 32 related compounds to three species of insects, and to discuss the mode of action of these compounds in relation to their inhibition of insect cholinesterase.

As yet, nothing has appeared in the literature regarding the mode of action of parathion, although from its structure it might be inferred to be an anti-cholinesterase similar to the related compounds tetraethyl pyrophosphate and diisopropyl fluorophosphonate (Mazur & Bodansky 1946, Chadwick & Hill 1947, DuBois & Mangun 1947).

MATERIALS.—The parathion (2) used in these studies was a molecularly distilled sample furnished by the American Cyanamid Company, who also supplied the compounds numbered in table 4 as 4, 6, 7, 8, 10, 11, 15, 17, 18, 19, 21, 22, 23, 24, and 25. The Victor Chemical Works supplied compounds 1, 3, 5, 9, 10, 11, 12, 13, 14, 16, 17, 20, 28, 30, 32, and 33. The Lubrizol Corporation supplied compounds 26 and 27, and the E. I. duPont Company, compound 29. In all cases the compounds were used as received, having been previously purified, usually by distillation, and their identity characterized by elemental analysis.

In addition to parathion, several of these compounds are being investigated as insecticides. Compound 1, diethyl *p*-nitrophenyl phosphate (Schrader's E-600)[2] is a colorless, mobile liquid, b.p.173°/1 mm. Hg., LD_{50} to mice about 2 mg. per kg. body weight (Schrader). It is soluble in water to about 0.2 per cent, and is about 300 times more stable to hydrolysis than tetraethyl pyrophosphate (Coates 1949).

Compound 32, tetraethyl pyrophosphate is a well-known insecticide. The material used in this study was a 100 per cent distilled ester, b.p. 132–134°/1 mm. Hg., LD_{50} to mice about 0.7 mg. per kg. body weight.

Compound 33, tetraethyl dithiopyrophosphate[3] is a slightly yellowish, mobile liquid, b.p. 135°/2 mm. Hg., subcutaneous LD_{50} to mice between 5 and 8 mg. per kg. (Schrader). It hydrolyzes very slowly in aqueous solution and is soluble to about 0.5 per cent (Schrader). The Victor Chemical Works gives the following properties: sp. gr. 1.196/25°, boiling point 110–113°/0.2 mm. Hg., and LD_{50} to white mice about 8 mg. per kg.

Compound 30, *p*-nitrophenyl ethyl benzene thiophosphonate[4] is a brownish liquid with a pronounced odor. It is described as stable to aqueous hydrolysis, and as being less toxic to warm-blooded animals than parathion.

METHODS.—The insecticidal activity of these compounds was evaluated by standard procedures used in this laboratory. The toxicological data on adult female house flies,[5] worker bees, and adult American cockroaches were accomplished by topical applications of measured drops (March & Metcalf 1949).

Cholinesterase determinations were made by the manometric method of Chadwick & Hill (1947) on a brei of 308 thoroughly macer ted bee heads per 100 ml. of a buffer ot 0.15 M NaCl, 0.04 M $MgCl_2$, and 0.025 M $NaHCO_3$. This was equivalent to about 8 mg. of brain tissue per ml. Two and six-tenths ml. of brei were used in each Warburg flask with 0.3 ml. of 0.2 M acetyl choline bromide. The inhibitory action of the compounds was determined by adding 01 ml. of a standard acetone solution of a compound to the flask to bring the final volume to 3 ml. It was found necessary to use acetone solutions because of the insolubility of the

[1] Pacific Slope Branch Paper, 1949.
[2] Para-Oxon. Victor Chemical Works.
[3] ASP-47, Victor Chemical Works.
[4] EPN, E. I. duPont Company.
[5] A laboratory strain of houseflies received from Dr. Y. P. Sun, Julius Hyman Company, Denver, Colorado.

compounds in water.[6] Following 5 minutes of flushing of the flasks with 95 per cent N_2 and 5 per cent CO_2, and 10 minutes shaking to reach equilibrium and to obviate the vapor pressure of the acetone, the amount of CO_2 produced over a 30 minute period at 37° C. was measured and compared with that produced by a control containing standard volumes of the same brei and other constituents as above, but with out an inhibitor. From this comparison the degree of inhibition was determined. Three or more levels of inhibition were measured for each inhibitor, and duplicate determinations were made for each concentration of inhibitor. The resulting curves were plotted as straight lines of log. molar concentration vs. probit of per cent inhibition and the value for 50 per cent inhibition read directly from the curve.

Because of the lack of sensitivity of the manometric method in the range of 90 to 100 per cent inhibition, supplementary determinations were made by the microtitrimetric method of Glick (1938), using a microburette accurate to ± 0.05 cu. mm., and employing N/20 HCl, bromthymol blue indicator and a sodium barbital buffer. Because of the interference of the eye pigment with the colorimetric endpoint, the brains were dissected from the head capsule before macerating in a micro Potter-Elvehjem homogenizer. Ten brains were used per ml. of 1.2 per cent Levy's solution (Patton 1946). Determinations were made on 0.1 ml. aliquots containing the equivalent of one brain.

DISCUSSON OF RESULTS.—The absolute toxicity of parathion to insects is of interest in view of the reported potency of the compound. The following LD_{50} values in micrograms per gram of body weight have been obtained by topical application of acetone solutions: female house fly 0.9 (24 hours); worker honey bee 3.5 (20 hours); female American cockroach 1.5 (120 hours). These values are low in comparison with other insecticides, and indicate that parathion is one of the most toxic materials available for insecticidal use.

Tobias *et al.* (1946a) have pointed out the extreme efficiency with which DDT and *gamma*-benzene hexachloride are absorbed and transported by the insect body to the site of action, so that the lethal dose by contact is almost equivalent to that by injection. The data in table 1 shows the results of a similar study with parathion and its oxygen analogue, paraoxon. It is apparent that the toxicity of either compound is about the same whether the material is applied topically or injected. However para-oxon is somewhat more toxic.

Table 1.—Toxicity of parathion and para-oxon to the American cockroach.

Compound	Dosage in Micrograms/ Roach	Per Cent Mortality in 120 Hours			
		Male Roach		Female Roach	
		Topical	Injected	Topical	Injected
Para-oxon	0.2	0	0	0	0
	0.4	0	50	0	14
	0.6	75	73	0	20
	0.8	100	60	50	60
	1.0	100	100	100	100
	2.0	100	100	100	100
LD_{50} in micrograms/gram		0.7	0.6	0.8	0.7
Parathion	0.6	29	14	0	12
	0.8	86	60	0	20
	1.0	86	100	12	44
	2.0	100	100	67	100
LD_{50} in micrograms/gram		0.9	0.9	1.5	1.0

Relative speed of toxic action.—Paraoxon acts considerably more rapidly than parathion at comparable dosages as shown by data in table 2.

Cholinesterase activity of bee brains.—The average production of CO_2 per bee brain per hour at 37° C. immediately after grinding was 127±3.2 (st. error) cu. mm. for 17 determinations. When the brei was allowed to stand overnight in the refrigerator before assay, considerably

[6] The water solubility of parathion has been estimated as 20 p.p.m. (Gleissner *et al.* 1947).

Table 2.—Speed of paralytic action of parathion and para-oxon topically applied to female house flies.

DOSAGE	TIME IN MINUTES FOR	
	50% paralysis	100% paralysis
Parathion		
5 micrograms/gram	65	80
50 micrograms/gram	35	60
Para-oxon		
5 micrograms/gram	15	25
50 micrograms/gram	1-2	5

more cholinesterase activity was apparent, presumably due to cell autolysis; the CO_2 production averaging 166 ± 1.7 (st. error) cu. mm. per hour for 19 determinations, or the equivalent of hydrolyzing 6.3 micromoles of acetyl choline per hour. Calculated on the basis of an average bee brain weight of 2.5 mg., this figure is equivalent to the hydrolysis of about 2.5 micromoles of acetyl choline per milligram of tissue per hour, a figure which is in good agreement with Richards & Cutkomp (1945) who obtained 1.01 micromoles per milligram per hour for bee brains at 25° C. and with Tobias *et al.* (1946b) who obtained 2.2 micromoles per milligram per hour for cockroach nerve cords at 37.6° C. (assuming acetyl choline).

Effects of parathion and tetraethyl pyrophosphate poisoning on cholinesterase activity in vivo.—To determine the effects of parathion and tetraethyl pyrophosphate poisoning on the cholinesterase activity in bees, 1 microgram (the approximate LD_{100} for parathion and TEPP) of each of these compounds was individually applied to a group of 150 bees. At intervals of 30 minutes, 60 minutes, 2 hours, 13 hours, and 18 hours, thirty bees from each group were decapitated and breis prepared from the brains as previously described. The data obtained on the relative cholinesterase activities is given in table 3. It will be noted that there is a progressive increase in the inhibition of the enzyme following *in vivo* poisoning and that the toxic symptoms exhibited by the bees can be directly correlated with the degree of cholinesterase inhibition. Mazur & Bodansky (1946) and Nachmansohn & Feld (1947) have shown a similar relation in mammals poisoned with diisopropyl fluorophosphonate. They also observed that animals killed with this material possessed almost no cholinesterase activity.

To obtain further data on this point, bees were poisoned by exposing them to a residue of 1 milligram of parathion on filter paper in a petri dish. When the bees were completely immoblized, their heads were cut off and the brains removed and assayed for cholinesterase activity by the titrimetric method of Glick (1938). Two determinations gave 97.5 per cent and 99.3 per cent inhibition respectively, indicating that at death the cholinesterase of the central nervous system is almost completely inhibited.

Effects of atropine on parathion poisoning.—Atropine is well known as a pharmacological antagonist for acetyl choline. Kilby and Kilby (1947) have shown that injections of atropine into rats at 10 mg. per kg. prior to poisoning with diisopropyl fluorophosphonate will delay the appearance of toxic symptoms and in some cases save the lives of animals administered lethal doses of diisopropyl fluorophosphonate. Similar experiments were tried with the American cockroach using atropine and parathion. Ten adult female roaches

Table 3.—Effect of parathion and tetraethyl pyrophosphate as *in vivo* inhibitors of bee brain cholinesterase. One microgram compound applied to thorax; 30 bees per determination.

TIME AFTER APPLICATION	TETRAETHYL PYROPHOSPHATE		PARATHION	
	Ch. E. Inhibition	Symptoms	Ch. E. Inhibition	Symptoms
30 minutes	90%	Complete knockdown	0	
60 minutes	94+%	Completely prostrate		
2 hours			48%	Violent agitation
13 hours			65%	60–70% knockdown; others lethargic
18 hours			90%	Completely prostrate; feeble leg and antennal movements

were each treated with 10 micrograms of atropine in 1.2 per cent Levy's solution administered by intra-abdominal injection. Thirty minutes later each roach was given a topical application of 2 micrograms of parathion (the 120-hour LD_{50} is 1.5 micrograms). In 5 hours, 5/10 of the atropinized insects were paralyzed, while 5/10 of a control group given the same application of parathion were paralyzed in the same time. All of the roaches of both test groups were dead in 3 days. Thus it appears that atropine is not appreciably effective in prolonging the life of parathion-poisoned roaches.

Relation of chemical structure to toxicity and cholinesterase inhibition.—Data on the relative effectiveness of various parathion derivatives as toxicants to bees and flies and as inhibitors of bee brain cholinesterase appears in table 4. Compounds containing the phosphoryl grouping are generally far more effective anticholinesterases than those containing the thiophosphoryl group. The former are also more toxic than the latter to the bee and fly, but the differences are of much lower magnitude. Thus the inhibitory ratios are for compounds 1 and 2, 1:50; 3 and 4, 1:300; 5 and 6, 1:5000; 10 and 11, 1:10; 14 and 15, 1:1; 17 and 18, 1:100; 23 and 24, 1:2000; and 32 and 33, 1:200. In comparison, the toxicity ratios for these pairs of compounds to the bee vary from 1:1 to 1:10. Compound 6, however, is anomalous in that although complete ineffective against bees, it was quite toxic to flies. The toxicity ratio of 5 and 6 was 1:1000 for bees and 2:1 for flies. This phenomenon raised the question as to whether compound 6 might not be an inhibitor of fly brain cholinesterase, and by using fly brains instead of bee brains, the data in table 5 was obtained.

It will be observed that *p*-nitrophenyl diisopropyl thiophosphate 6 is non-toxic to bees and is not an effective inhibitor of bee brain cholinesterase but is toxic to flies and is an active inhibitor to fly brain cholinesterase. In contrast, parathion and para-oxon are about equally effective against the two organisms, both as toxicants and anti-cholinesterases. Therefore it appears that there are specific biochemical differences in the cholinesterase of flies and bees. To our knowledge this is the first example of specificity of insecticidal action traceable to a specific difference in enzyme properties. It is interesting that the closely related compound, *p*-nitrophenyl diisopropylphosphate, is toxic to both bees and flies.

The effectiveness of the compounds is directly dependent upon the nature of the alkyl groups, methyl homologues 3, 4 being slightly more toxic than ethyl 1, 2, but less effective as anticholinesterases, while propyl 7 and isopropyl are less effective. This is in considerable contrast to the dialkylfluorophosphonates where the diisopropyl compound was more effective to rats than either the methyl or ethyl-esters (Mazur & Bodansky 1946). This may be explainable in terms of solubilities and transport to the site of action.

The effect of substituent groups in the phenyl ring is highly specific. The unsubstituted compounds 10, 11 are nearly inactive, while substitution with chlorine 14, 15, 16 or methoxy 19 is little more effective. *Para*-substitution with a methyl group 17, 18 increases the effectiveness. Nitration of the ring in *ortho*-or *para*-positions 12 greatly increases the activity which reaches a maximum with *para*-orientation 1, 2, 3, 4. The latter compounds were the most effective of those studied, both as inhibitors and as toxicants, and were more effective than the corresponding pyrophosphates 31, 32. Para-oxon 1 inhibited bee brain cholinesterase at dilutions as great as 1×10^{-9} molar. This activity is diminished by the presence of additional ring substituents such as chloro-, methyl-, or a second nitro-group 13, 22, 23, 24, 25, and is entirely lost by reduction of the nitro-group to form an amino-group 21. The activity is markedly reduced by replacement of *para*-nitrophenyl by *para*-nitrobenzyl 26, 27 and is destroyed in the *para*-nitroaniline derivative 28. Compounds 9 and 33 incorporating the bis-dimethylamido grouping are completely inactive to bees and flies and are very poor inhibitors of bee brain cholinesterase. The lack of toxicity of the dimethylamido-analogues of para-oxon and tetraethyl pyrophosphate is puzzling because Schrader indicates that these materials possessed considerable toxicity to aphids. In order to ascertain if this lack of toxicity to bees and house flies was due to failure of the materials to penetrate the insect

Table 4.—Relation of chemical structure of certain organic phosphates to cholinesterase inhibition and to toxicity.

Compound No.	Compound	IN_{50}[1] for Bee Brain Cholinesterase	Topical LD_{50}[2] to Worker Bee	Topical LD_{50}[2] to House Fly
	A. Effect of Alterations of Aliphatic Group			
(1)	diethyl *p*-nitrophenyl phosphate $p\text{-}O_2NC_6H_4O\overset{\overset{O}{\|}}{P}(OC_2H_5)_2$	1.9×10^{-8}	0.6	0.5
(2)	diethyl *p*-nitrophenyl thiophosphate $p\text{-}O_2NC_6H_4O\overset{\overset{S}{\|}}{P}(OC_2H_5)_2$	1×10^{-6}	3.5	0.9
(3)	dimethyl *p*-nitrophenyl phosphate $p\text{-}O_2NC_6H_4O\overset{\overset{O}{\|}}{P}(OCH_3)_2$	4.2×10^{-8}	0.3	1
(4)	dimethyl *p*-nitrophenyl thiophosphate $p\text{-}O_2NC_6H_4O\overset{\overset{S}{\|}}{P}(OCH_3)_2$	1.3×10^{-5}	1.7	1
(5)	diisopropyl *p*-nitrophenyl phosphate $p\text{-}O_2NC_6H_4O\overset{\overset{O}{\|}}{P}[OCH(CH_3)_2]_2$	2.8×10^{-6}	5	10
(6)	diisopropyl *p*-nitrophenyl thiophosphate $p\text{-}O_2NC_6H_4O\overset{\overset{S}{\|}}{P}[OCH(CH_3)_2]_2$	1.4×10^{-2}	>1000	4.2
(7)	dipropyl *p*-nitrophenyl thiophosphate $p\text{-}O_2NC_6H_4O\overset{\overset{S}{\|}}{P}(OC_3H_7)_2$	1.6×10^{-5}	30	4
(8)	ethyl, butyl *p*-nitrophenyl thiophosphate $p\text{-}O_2NC_6H_4O\overset{\overset{S}{\|}}{P}\begin{matrix}OC_2H_5\\ \diagdown\\ OC_4H_9\end{matrix}$	2×10^{-4}	7	3.2
9)	bis-(dimethylamido) p-nitrophenyl phosphate $p\text{-}O_2NC_6H_4O\overset{\overset{O}{\|}}{P}[N(CH_3)_2]_2$	3×10^{-2}	>1000	>500
	B. Effect of Alterations of Aromatic Group			
(10)	diethyl phenyl phosphate $C_6H_5O\overset{\overset{O}{\|}}{P}(OC_2H_5)_2$	3×10^{-4}	>1000	>500
(11)	diethyl phenyl thiophosphate $C_6H_5O\overset{\overset{S}{\|}}{P}(OC_2H_5)_2$	3×10^{-2}	>1000	>500
(12)	diethyl *o*-nitrophenyl phosphate $o\text{-}O_2NC_6H_4O\overset{\overset{O}{\|}}{P}(OC_2H_5)_2$	3.3×10^{-7}	1	7
(13)	diethyl 2,4-dinitrophenyl phosphate $2,4\text{-}(O_2N)_2C_6H_3O\overset{\overset{O}{\|}}{P}(OC_2H_5)_2$	2.9×10^{-7}	75	155

[1] Molar concentration for 50 per cent inhibition of enzyme *in vitro*.
[2] Median lethal dosage by topical application in micrograms per gram of body weight, assuming an average weight of 100 mg. per bee and 20 mg. per fly.

Table 4.—Continued

Compound No.	Compound	IN_{50}[1] for Bee Brain Cholinesterase	Topical LD_{50}[2] to Worker Bee	Topical LD_{50}[2] to House Fly
(14)	diethyl *p*-chlorophenyl phosphate $p\text{-}ClC_6H_4OP(OC_2H_5)_2$	4.2×10^{-4}	> 100	150
(15)	diethyl *p*-chlorophenyl thiophosphate $p\text{-}ClC_6H_4OP(OC_2H_5)_2$	3.8×10^{-4}	>1000	250
(16)	diethyl *o*-chlorophenyl phosphate $o\text{-}ClC_6H_4OP(OC_2H_5)_2$	5.7×10^{-5}	> 100	250
(17)	diethyl *p*-methylphenyl phosphate $p\text{-}CH_3C_6H_4OP(OC_2H_5)_2$	6.2×10^{-6}	200	>500
(18)	diethyl *p*-methylphenyl thiophosphate $p\text{-}CH_3C_6H_4OP(OC_2H_5)_2$	7.8×10^{-4}	>1000	>500
(19)	diethyl *p*-methoxyphenyl thiophosphate $p\text{-}CH_3OC_6H_4OP(OC_2H_5)_2$	3.2×10^{-4}	>1000	>500
(20)	diethyl *p*-tert-butylphenyl phosphate $p\text{-}(CH_3)_3CC_6H_4OP(OC_2H_5)_2$	1.1×10^{-4}	> 100	>500
(21)	diethyl *p*-aminophenyl thiophosphate, hydrochloride $HCl\cdot H_2NC_6H_4OP(OC_2H_5)_2$	7.8×10^{-3}	>1000	—
(22)	diethyl 2-chloro-4-nitrophenyl thiophosphate $2\text{-}Cl,4\text{-}O_2NC_6H_3OP(OC_2H_5)_2$	3×10^{-5}	20	0.8
(23)	diethyl 2-nitro-4-chlorophenyl phosphate $2\text{-}O_2N,4\text{-}Cl_2C_6H_3OP(OC_2H_5)_2$	3.4×10^{-7}	10	23
(24)	diethyl 2-nitro-4-chlorophenyl thiophosphate $2\text{-}O_2N,4\text{-}Cl_2C_6H_3OP(OC_2H_5)_2$	1.4×10^{-4}	30	9
(25)	diethyl 2-nitro-4-methylphenyl thiophosphate $2\text{-}O_2N,4\text{-}CH_3C_6H_4OP(OC_2H_5)_2$	1.1×10^{-4}	>1000	450
	C. Compounds with Altered Aromatic Linkages			
(26)	diethyl *p*-nitrobenzyl thiophosphate $p\text{-}O_2NC_6H_4CH_2OP(OC_2H_5)_2$	1.8×10^{-5}	>1000	26
(27)	diethyl *p*-nitrobenzyl dithiophosphate $p\text{-}O_2NC_6H_4CH_2SP(OC_2H_5)_2$	2.2×10^{-5}	>1000	21
(28)	diethyl *p*-nitroanilido phosphate $p\text{-}O_2NC_6H_4NHP(OC_2H_5)_2$	1×10^{-4}	> 100	>500

Table 4.—Continued

Compound No.	Compound	IN_{50}[1] for Bee Brain Cholinesterase	Topical LD_{50}[2] to Worker Bee	Topical LD_{50}[2] to House Fly
	D. Phosphonic Acid Esters			
(29)	ethyl *p*-nitrophenyl benzene thiophosphonate $O_2NC_6H_4OP(S)(OC_2H_5)(C_6H_5)$	8.2×10^{-7}	3	1.9
(30)	diethyl benzene thiophosphonate $C_6H_5P(S)(OC_2H_5)_2$	1.6×10^{-4}	> 100	>500
	E. Related Aliphatic Phosphates			
(31)	tetraethyl pyrophosphate $(C_2H_5O)_2P(O)\text{-}O\text{-}P(O)(OC_2H_5)_2$	2.3×10^{-8}	1.2	—
(32)	tetraethyl dithiopyrophosphate $(C_2H_5O)_2P(S)\text{-}O\text{-}P(S)(OC_2H_5)_2$	1×10^{-6}	5	5
(33)	octamethyltetramido pyrophosphate $[(CH_3)_2N]_2P(O)\text{-}O\text{-}P(O)[N(CH_3)_2]_2$	$>1.2\times10^{-3}$	> 100	>500

cuticle, both bis-(dimethylamido) *p*-nitrophenyl phosphate 9 and octamethyltetramido pyrophosphate 33 were made up as 10 per cent acetone solutions and applied topically and injected intraabdominally into the American cockroach at 100 micrograms per gram of body weight. Such applications produced neither mortality nor toxic symptoms after 120 hours, indicating that these compounds are ineffective to the roach, as well as the honey bee and house fly. Compound 29 is most interesting as one of the ethoxy groups has been replaced by a phenyl group, resulting in a compound which is about as effective as parathion both as an inhibitor and as a toxicant.

In general there is a direct relationship between *in vitro* cholinesterase inhibition and *in vivo* toxicity. In the case of compounds 26 and 27, the low toxicity values in light of median inhibitory action may possibly be explained by lack of transport to the site of action. Compound 13 which exhibits a similar relationship, may be too polar by virtue of the two nitro-groups to penetrate cuticle or membranes. In no case however, was there evidence for high toxicity in the absence of enzyme inhibition. Thus it may be postulated that the primary cause for toxicity in this series of compounds is due to the inhibition of cholinesterase. It is possible that future work may show that other enzyme systems, such as other esterases, are affected in a like manner (Jansen *et al.* 1949).

SUMMARY AND CONCLUSIONS.—(1) The toxicity and mode of action of parathion and 32 related compounds were studied by means of topical applications of known amounts of the materials to adult female house flies and worker bees, and by measurements of the inhibitory action on bee brain cholinesterase.

Table 5.—Comparative effects of several parathion derivatives to bees and flies.

Compound	LD_{50} in micrograms per gram		IN_{50} in moles	
	Worker Bee	House Fly	Bee Brain	Fly Brain
parathion	3.5	0.9	1×10^{-6}	4.5×10^{-7}
para-oxon	0.6	0.55	1.9×10^{-8}	2.6×10^{-8}
p-nitrophenyl diisopropyl thiophosphate	>1000	4.2	1.4×10^{-2}	2×10^{-5}

(2) Parathion and para-oxon were both readily absorbed by the cuticle of the American cockroach so that the LD_{50}'s for topical application and for injection were almost identical.

(3) Para-oxon was more toxic than parathion to the insects studied and produced toxic effects much more rapidly.

(4) *In vivo* studies with parathion have shown that the symptoms of bees poisoned with parathion can be directly correlated with the extent of inhibition of bee brain cholinesterase, and that the enzyme is almost completely inhibited at the point of death.

(5) The compound *p*-nitrophenyl diisopropyl thiophosphate is ineffective against bees and does not inhibit bee brain cholinesterase, but is toxic to flies and inhibits fly brain cholinesterase.

(6) Extensive investigations have been made of the relation of the chemical structure of parathion derivatives to their toxicity to bees and flies, and their inhibitory action on bee brain cholinesterase. The following points are of interest:

a. Compounds with phosphoryl-groups are more active than those with thiophosphoryl-groups.
b. Methyl and ethyl esters are more active than higher homologues.
c. A high degree of effectiveness is obtained only when a nitro-group is present on the aromatic ring and maximum effectiveness is associated with a *para*-nitro group.
d. The effectiveness of the compound is destroyed by the introduction of methylene- or amino-groups between the phenyl ring and the phosphorous atom.
e. One of the ethyl groups may be substituted by a phenyl-group without markedly decreasing the activity, but replacement of both ethyl groups with bis-(dimethyl amido)-groups completely destroys the activity to the fly, bee, and the American cockroach, and the inhibitory action to bee brain cholinesterase.

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Studies on the Transmisson of the Virus Causing Phloem Necrosis of American Elm, With Notes on the Biology of Its Insect Vector

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Phloem necrosis of American elm, a virus disease of unknown origin, is one of the most destructive forest and shade tree diseases known. Once a tree is affected by it, death is certain. Although it has apparently been present in the Ohio River Valley at least since 1882 (Garman 1899, Forbes 1912), it was not considered a disease of major importance until within recent years. The importance of the disease was realized upon its invasion of areas where American elm has high value as a street and shade tree. The disease now occurs over a widespread area in the Midwest, having been reported from the following States: Ohio, Indiana, Illinois, Missouri, Iowa, Nebraska, Kansas, Oklahoma, Arkansas, Mississippi, Tennessee, Kentucky, and West Virginia (Bretz & Swingle 1946), and Alabama and Georgia (Swingle *et al.* 1949). In many of the larger cities in this region thousands of valuable shade and street trees have been killed within recent years.

Since 1940 the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry, Soils, and Agricultural Engineering have cooperated in maintaining a laboratory at Columbus, Ohio, for studying the disease and its possible insect vectors. Hundreds of tests, involving the use of over 90 species of insects, have been conducted in an effort to identify the insect species responsible for transmission of the virus. However, with the possible exception of certain tests with leafhoppers in the genus *Erythroneura*, the efforts ended in failure until a series of small-scale tests with the leafhopper *Scaphoideus luteolus* Van D. were established in 1946. These tests left no doubt that this leafhopper actually transmitted the virus (Baker 1948). Nevertheless, when the results of the 1946 tests became known in 1947 an extensive series of similar tests with the species was established in an effort to confirm the results. The purpose of the present paper is to report the results already obtained in the duplicate tests, and to furnish certain preliminary information on the life history, habits, and distribution of the vector species.

Results of 1947 Transmission Tests.—An extensive series of duplicate tests was established in July 1947, after it had been determined that certain of the elm seedlings placed under test with the leafhopper *Scaphoideus luteolus* in July 1946 had developed phloem necrosis symptoms.

The leafhoppers used were collected almost entirely as nymphs—the only stage in which the species can be collected easily and in numbers sufficient for testing. The nymphs were exposed to the virus by confining them on diseased-elm foliage in cheesecloth sleeves for periods ranging from 5 to 13 days. After feeding on diseased trees they were divided into groups of 25 insects, each group of which was then placed on a potted, healthy, 2-year-old elm seedling. After feeding for a few days on these seedlings the survivors were removed and placed on a second series of healthy plants, where they were again permitted to feed. Further transfers to additional healthy plants were made at various intervals, depending on survival of test insects. Therefore each lot of insects fed on at least two healthy seedlings in succession, after being removed from diseased foliage; many fed on three healthy seedlings; a few fed on four; and at least two fed on five trees in succession. After the insects were taken off these seedlings the cloth sleeves were removed and the seedlings were placed in a cloth-covered shelter-cage, where further precautions against feeding by other insects were taken by spraying the cage and seedlings with DDT. Before the beginning of the 1948 growing season the seedlings were removed from the clay pots and planted in the ground in the shelter cage.

In these duplicate tests, a total of 119 2-year-old elm seedlings, grown from seed in insect-proof cages, were exposed to the

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feeding of infective insects. Hundreds of similar seedlings, grown under the same conditions, were not exposed to insects and these served as checks on the results of this work. Further checks were furnished by several hundred other seedlings in cages that had been used in tests with other insect species.

Under field conditions, first symptoms of phloem necrosis usually are not visible before mid-June. Exceptions occur among trees that become diseased so late in the growing season that they do not die until the following spring. Early in the spring the latter may be identified soon after the advent of the foliar season by the failure of their young leaves to grow normally. While leaf expansion of healthy trees continues unabated until leaves reach full size, the leaves of these diseased trees usually stop growing by the time they are from one-fourth to one-half grown, and often are from pale green to yellow green in color. Such trees usually die early in the season, before the first appearance of disease symptoms in trees that come out normally, but develop symptoms later.

Since it was possible that some of the test trees had already become diseased in the fall of 1947, and might have died before the date when foliar symptoms normally occur, they were examined late in May 1948. At that time several seedlings had stunted foliage, indicating a diseased condition. Some of these stunted seedlings were dug at this time, so that a more thorough diagnosis of virus infection could be made by examining the fibrous root-systems, and the phloem in the basal portions of the main stems. It was found that many of the smaller roots were dead and the inner phloem surface was butterscotch in color and emitted a distinct odor of wintergreen—positive evidence of phloem necrosis.

The remainder of the seedlings with stunted foliage were left in the ground a few days to await further development of symptoms. All continued to decline and, just before they were completely dead, they were dug and the living portions of the phloem were examined. All bore unmistakeable phloem necrosis symptoms. By the latter part of July still others had developed symptoms, and the presence of of the disease was confirmed. Altogether, a total of 22, or 18.6 per cent, of the 1947 test trees developed symptoms and died in 1948. Examination of the hundreds of of check seedlings, and the hundreds of seedlings under test with other insect species, failed to disclose the presence of a single additional diseased tree. The remainder of these trees are being left in the ground to await the possible development of symptoms.

The primary purpose of these tests, which has been fulfilled, was to duplicate if possible the results of the 1946 tests. They were not especially designed to show the length of the incubation or latent period of the virus in the insect that was necessary before the disease could be transmitted. Evidence was obtained, however, which indicates that a period of several days must elapse after insects feed on diseased foliage before they can transmit the virus. For instance, when insects were allowed to feed on a series of healthy trees for 20 days after feeding on diseased foliage only 5.5 per cent of the healthy trees developed disease symptoms. However, in a second series of trees to which these insects were transferred after an incubation period of 20 days, and on which they were allowed to feed for 30 days thereafter, a total of 34 per cent of the healthy trees became diseased. Additional research is necessary to show whether or not the lower percentage of transmission recorded in the first series of trees was due to a latent period of the virus in the insects, or to a shorter period of feeding on these trees than on those in the second series.

LIFE HISTORY, HABITS, and DISTRIBUTION OF *Scaphoideus luteolus*.—Beyond its description, plus a few distribution records and occasional references to host plants, the literature contains practically nothing about this species. This is hardly surprising because it has not previously been known to be economically important, and because it is a species that usually does not show up in abundance in insect collections made at random. Even where elm is swept, adults are seldom found in large numbers, even when search is made for them in stands harboring heavy nymphal populations. This fact may be accounted for largely by the habit of the adult of frequenting the inner parts of the crown until well along in the season. Late in the summer, although adults may disperse to other parts of the crown, it is still difficult to collect many of them be-

cause so much of the foliage is beyond the collector's reach. It is probably because of these habits of the insect that the species has not been known to be as common as it is.

Scaphoideus luteolus belongs to the leafhopper subfamily Athysaninae. In the adult stage it closely resembles certain other species in the genus. These resemblances may be so close that the species can be separated only by a study of structural differences in the internal genitalia of males. A few years ago the species was described by DeLong and Mohr (1936) as *S. baculus*. However, P. W. Oman, of the Division of Insect Identification, reports that their *S. baculus* is in fact *S. luteolus* Van D. Although adults of the species are difficult to separate from related species, the opposite is true of nymphs. After the second instar practically all nymphs are dark brown with the exception of a transverse white band on the dorsum. This white band lies just behind the thorax and covers the first two and part of the third abdominal segments. Specimens are rarely encountered where this band is obscure or absent. The value of this nymphal character in identifying the species is indicated by the fact that in all our studies of insects associated with elm in Ohio and other widely scattered sections of the Midwest in recent years, no nymphs of another leafhopper species that closely resembles *S. luteolus* have been encountered on elm.

Prior to the study here reported, apparently but little was known about the host-plant preferences of *Scaphoideus luteolus*. Several years ago Osborn (1928, p. 259) reported collecting it from elm; but more recently De Long (1948), in discussing it under the name *S. baculus*, stated that its food plant was unknown. In surveys of elm-inhabiting insects conducted in the course of this study, it was soon discovered that the species could be collected consistently from elm, but seldom showed up in collections from associated vegetation. As early as 1941 it was found that the nymphal stage was found only on elm. Subsequent observations have failed to disclose the presence of nymphs on any other plant. Although surveys of elm-inhabiting insects have disclosed the presence of at least 150 species of sucking insects on elm at one time or another, they have also shown that very few of these are as abundant on elm as on associated plant species. The records suggest that, with the possible exception of certain insects in the genus *Erythroenura*, *S. luteolus* comes closer than any other leafhopper to being confined entirely to elm in the Midwest.

Since *Scaphoideus luteolus* was found to transmit the virus causing elm phloem necrosis, certain details of its life history have been tentatively determined. Insect eggs found buried in the cork parenchyma of elm bark were allowed to hatch on moist blotting paper in culture dishes in the laboratory. Many of the nymphs hatching from these eggs were reared into the later instars on elm in the laboratory and were found to be this species. A few of them were reared to the adult stage.

The species overwinters in the egg stage in Ohio, hatching early in the spring, soon after elm foliage first appears. In 1948 first nymphs were seen at Kansas City, Mo., on April 26. At Columbus, Ohio, the first nymphs were not seen until 2 weeks later, May 11. Field observations indicate that hatching may occur over a period of several weeks, since it is not uncommon to find first-, second-, and third-instar nymphs feeding together on a single elm leaf. Even under the controlled temperatures of laboratory conditions, it took several weeks for all the eggs in infested elm bark to hatch.

In the laboratory a total of five nymphs hatched from eggs were reared to the adult stage on elm. Of these four were males, two of which required 36 days to complete nymphal development. The other two required 37 days. The fifth specimen, a female, spent 42 days as a nymph. Each sex had five nymphal instars.

Under field conditions it may take a little longer for the first nymphs to reach the adult stage than it does under the even temperatures of the laboratory. In any event, although hatching began as early as May 11 in the Columbus area in 1948, it was not until 49 days later, on June 29, that the first adult of the season was seen. From June 29 to August 25 both nymphal and adult stages were present, although nymphs were scarce by the end of July. Just how long adults live was not accurately determined. Adults in a sleeve over elm foliage lived for 68 days, or until they and the foliage on which they were

confined were killed by the first severe frost of the season, on October 15. Data are not available on the length of either the preoviposition period or the egg-laying season.

Since the eggs are laid in roughened bark, the newly hatched nymphs are forced to wander in search of foliage on which to feed. Therefore the foliage nearest the trunk or limbs becomes infested first. They are most abundant on the leaves of tiny branchlets growing from the trunks. Many of these branchlets never exceed 2 to 3 inches in length and they bear only two or three leaves each. It is not unusual to find a dozen or more newly emerged nymphs clustered on the undersurface of one of these leaves.

Observations of feeding habits indicate that the species feeds principally on the midribs and larger leaf veins on the undersurfaces of leaves. Excessive feeding may cause the apical portions of leaves to die. Where this occurs the injury is not unlike tip-burn of potato, caused by the feeding of the potato leafhopper, *Empoasca fabae* (Harris). As the nymphs continue to grow they tend to disperse. Nevertheless, until the end of this stage they are most abundant on the foliage of these trunk branchlets. Not only may nymphs be found most easily on this foliage, but in the early days of the adult stage adults themselves may be collected easily from the stems and twigs of the branchlets, by using an aspirator. In fact, much larger numbers were collected from these branchlets by this method late in July and early in August 1948 than were collected from the same trees by sweeping the outer foliage with a net. After mid-August, however, the reverse was true, indicating that most of the adults had dispersed.

Scaphoideus luteolus is widely distributed in the Eastern States. In surveys it has been collected in New Jersey, Pennsylvania, Ohio, West Virginia, Kentucky, Tennessee, Mississippi, Kansas, Nebraska. Iowa, Missouri, Illinois, Wisconsin and Indiana. Medler (1942), although referring to it as *baculus*, reports it from Minnesota; and P. W. Oman reports having seen specimens from the following additional States: New York, Maryland, Virginia, Alabama, and Georgia. Thus, it is known to be present not only as far north, west, and south as phloem necrosis of elm is known to occur, but in several States east and north of the known limits of disease distribution.

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DR. ANDRE TO IOWA STATE COLLEGE

Dr. Floyd Andre, Assistant Dean of Agriculture, Assistant Director of the Agricultural Experiment Station and Agricultural Extension Service, College of Agriculture, University of Wisconsin, has been appointed Dean of Agriculture, Director of the Agricultural Experiment Station and Agricultural Extension Service, at Iowa State College, effective July 1, 1949. A 1931 graduate and staff member of Iowa State College from 1934 to 1938, before joining the Wisconsin staff in 1946, Dr. Andre served as Principal Entomologist and Experiment Station Administrator in the Office of Experiment Stations of the United States Department of Agriculture in Washington, D. C.

Methyl Bromide Fumigation of Commodities for the Destruction of White-Fringed Beetle Eggs

GEORGE R. SWANK, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Eggs of the white-fringed beetles (*Graphognathus* spp.) may be found cemented to any object in contact with the soil. Commodities such as peanuts, hay, or seed crops, which are in contact with the soil in quarantined areas during oviposition, thereby become a dissemination hazard. Between September 1941 and March 1946 tests were made at Gulfport, Miss., and Burgaw, N. C., to develop methyl bromide fumigation schedules at normal atmospheric pressure so that suspect commodities could be fumigated and moved without presenting this hazard. Eggs of at least two species of white-fringed beetles were used. The results are considered to be applicable to all species of these beetles, as previous work has shown little difference in susceptibility to methyl bromide by the various species.

A total of 262 fumigations were made and 435,500 eggs were used. Previous experience had shown the egg to be the most resistant stage to methyl bromide; hence heavier dosage schedules were necessary. The use of these heavy dosages entailed research as to the effect of the fumigations on the commodities as well as on the mortality of eggs.

MATERIALS AND METHODS.—Tests were made in four metal-lined chambers, each provided with a fan for circulation. Two of the chambers had thermostatically controlled heating elements and insulated walls; one was an experimental chamber of 116-cubic-foot capacity, and the other a 350-cubic-foot portable chamber built by the North Carolina Department of Entomology. Two types of smaller units, a 19.6-cubic-foot vaccum chamber, and an 8-cubic-foot water-seal drum-type fumigation chamber, were also used.

The desired dosage of methyl bromide was measured as a liquid in a glass dispenser and applied through a closed system. When injections were made at low temperature, complete volatilization of methyl bromide was assured either by injection through coils immersed in hot water or by use of a heated drip pan.

The average temperature was recorded for each treatment. Often this average was simply the mean of the maximum and minimum limits reached during the exposure period. At other times the temperature was maintained by the thermostatically controlled heating units. As no differences in mortality were detected between tests by the two methods, no attempt is made to group them separately.

Where circulation was desired, an electric fan was operated in the chamber for the first 15 minutes of the exposure period.

Tests with a tarpaulin coated with ethyl cellulose were unsatisfactory. Even a dosage double that necessary in the metal-lined chambers failed to cause complete mortality.

Preliminary experiments revealed that exposure periods of 12 hours or less required relatively high dosages; therefore overnight periods of 16 to 20 hours were adopted. As there was little difference in results, all exposure periods are combined as 16 hours or longer.

Samples of white-fringed beetle eggs were exposed to various concentrations of methyl bromide in empty chambers, or in chambers loaded with baled hay, peanuts, peanut hulls, seed cotton, or gin trash. Samples were placed on the outside of the commodities, and perforated brass points filled with eggs were driven into the commodities to test penetration.

Absorption by peanut hay or by soybean hay was not excessive, since there were no appreciable differences in mortality results between empty chambers and ones filled with hay. However, there was a decrease in mortality when a load of unshelled peanuts was included.

The eggs were collected from oviposition cages in which had been placed chips of wood upon which the adults deposited the eggs. Each collection of eggs was kept in a dated paper bag. Each sample was composed of eggs less than 10 days old, and eggs over 30 days old. In these older eggs the larvae had already formed and were only waiting for the egg shell to be moistened so that they could hatch. Such eggs can be kept viable for several months if they are placed in dry storage.

Table 1.—White-fringed beetle eggs hatching after fumigation with various dosages of methyl bromide at different temperature levels. Exposure periods 16 hours or more at normal atmospheric pressure.

Pounds per 1000 Cubic Feet	Temp. (°F.)	Number		
		Tests	Eggs Fumigated[1]	Eggs Hatching
5	35	1	1500	0
4.5	35	1	1625	0
4	35	4	6125	4
	45	1	2625	0
	50	3	5200	0
	60	1	2100	0
	70	1	1500	0
	80	1	1500	0
3.5	35	2	2700	8
	40	1	1625	0
	45	3	7755	0
	50	1	2625	0
3	35	2	3125	0
	40	3	7100	222
	45	5	9625	2
	50	2	4375	4
	55	2	4425	37
	60	3	7200	0
	70	1	1050	0
	80	1	2100	0
	85	1	2250	0
2.5	30	1	1625	84
	45	3	6450	36
	50	2	2625	9
	55	2	4125	0
	60	3	7000	0
	75	1	1750	0
2	40	1	2000	0
	45	1	1200	0
2	50	7	16425	16
	55	3	7600	0
	60	5	11750	0
	65	4	7425	0
	70	1	1800	0
	75	1	2400	0
	80	4	8400	0
	85	3	5000	0
1.5	40	1	2500	43
	45	1	1200	2
	50	2	4125	2
	55	3	6750	3
	60	2	4250	0
	65	7	15825	0
	70	4	7975	0
	75	6	11000	8
	80	5	11300	0
	85	2	4400	0
	90	2	4750	0
1	50	1	1125	1
	60	1	1800	0
	65	5	8445	8
	70	6	11475	318
	75	3	6900	22
	80	8	18250	151
	85	6	14450	1
	90	1	2000	0
0.5	80	2	5250	119
	85	2	5250	239
	90	1	2000	3
	95	2	5250	119

[1] Estimated.

After exposure to methyl bromide the samples from a series of tests, including the checks, were placed individually in covered salve tins and moistened. Hatching records were taken at 3, 6, and 10 days and every 10 days thereafter until three consecutive negative observations were obtained for the whole series.

The number of eggs per sample was estimated; therefore the hatching records are not entirely accurate on a percentage basis. Because in these studies the larvae hatching or not hatching was the most important consideration, the number of larvae hatching is presented rather than the percentage. Untreated eggs had a high viability, which slowly decreased after they were about 40 days old.

RESULTS OF TESTS.—Data from all tests are listed in table 1 according to the dosage schedules used and grouped in temperature steps represented by the midpoint of each 5° variation. The check samples are not listed because the hatching was satisfactory in all of them. The principal objective of the checks was to establish the viability of eggs in the treated samples, not to permit comparison of percentages.

REACTION OF COMMODITIES TREATED.—No difference in quality or taste was evident in peanuts even when they were fumigated at dosages twice those necessary, or when fumigated three times. Dudley *et al.* (1940) determined that peanuts had only 84 p.p.m. of bromine when analyzed 24 hours after fumigation with 3 pounds of methyl bromide per 100 cubic

feet for 24 hours, and demonstrated that rats suffered no detriment when fed a diet containing as high as 284 p.p.m. for 20 weeks. Reeves *et al.* (1947) found that cottonseed fumigated for 20 hours with 5 pounds of methyl bromide per 1000 cubic feet exhibited up to 176 p.p.m. of bromine when analyzed, but that all the bromine was in the press cake, not in the oil, when the seed was pressed. Such residues are now considered nominal and noninjurious in the food of man or the higher animals, and are generally accepted in grains, cereals, and food products that are fumigated in large quantities. In California hay has been fumigated in large quantities. Apparently, therefore, there is little hazard of rendering unfit for consumption such products as would be associated with this problem.

Various garden and field seeds and peanuts germinated about normally after fumigation with dosages of methyl bromide sufficient for control of the white-fringed beetle eggs.[1] With seeds of poor quality there was a reduction in germination. When seeds of high vitality were fumigated with double dosages, germination was reduced about 25 per cent. Growing plants will not tolerate these dosage schedules.

There were also instances of retardation in germination. Collard seeds fumigated with dosages sufficient for control of the eggs lagged about 2 days behind the checks; seed fumigated with double dosages lagged about 12 days.

SCHEDULES RECOMMENDED FOR QUARANTINE USE.—On the basis of the mortality data given in table 1 the fumigation schedules given below have been recommended for the use of the white-fringed beetle project and are now in use. The schedules are as follows (all exposures are for at least 16 hours).

The recommendations stipulate the volatilization of the methyl bromide before it is introduced into the chamber, and the operation of a fan for 15 minutes thereafter. The temperature of the commodity may be calculated from its temperature at the beginning, the weather conditions for the preceding 24 hours, and the current forecast, where fumigation is done in a chamber lacking thermostatically controlled heating to maintain the starting temperature level.

Average Temperature of Commodity During Exposure (°F.)	*Dosage of Methyl Bromide (Pounds per 1000 Cubic Feet)*
30–40	5.5
40–50	4.5
50–60	3.5
60–75	2.5
75–90	1.5

Only approved chambers are to be used, which are required to have sheet-metal linings and a fan or blower for circulation, and must pass a pressure test whereby an internal pressure of 50 mm. on a kerosene-filled open-arm manometer requires 22 seconds or more to recede to 5 mm.

SUMMARY.—Experiments were carried out in Mississippi and North Carolina to develop methyl bromide fumigation schedules for such commodities as hay, peanuts, or seed crops, which might disseminate white-fringed beetle eggs. On the basis of the mortality data obtained after exposure periods of 16 hours or more, schedules for quarantine use were drawn up. The recommended schedules ranged from a dosage of 5.5 pounds of methyl bromide per 1000 cubic feet for 16 hours at the 30°–40° F. level to 1.5 pounds at 75°–90°.

There was no apparent detriment to taste or quality of peanuts, and a review of literature indicated there would be only nominal bromine residues, which would not affect consumption, in any of the commodities that would probably be fumigated. Seeds germinated normally at the dosage levels recommended for use. In some types of seeds germination was retarded, and at double dosages there was about 25 per cent reduction in the germination of all seeds.

[1] The germination tests were made by W. H. Darst of the North Carolina Seed-Testing Laboratory.

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Codling Moth Investigations on the Payne Variety of English Walnut in Northern California

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The colding moth, *Carpocapsa pomonella* (L.) is one of the most destructive insects attacking Payne walnuts in Northern California. Investigations on the control of this pest were undertaken by the senior author in 1942 in the Linden area of San Joaquin County. The results obtained up to and including 1944 have been reported upon by Michelbacher (1945). Since that time the investigation has been expanded. Extensive studies have been continued in the Linden area, and in 1947 experimental work was undertaken in the agricultural region surrounding San Jose in Santa Clara County. Besides these locations some studies have been conducted in the Gridley area in the Sacramento Valley.

Principal investigations have been directed towards improving control measures used against the pest. These have included (1) studies on the proper timing of spray applications; (2) testing of new insecticides; (3) the effect of insecticides upon pests other than the codling moth; (4) spray mixtures that produce most effective control; (5) methods of application; and (6) the effectiveness of combination sprays for control of codling moth and walnut aphids.

Because of climatic differences at Linden and San Jose, the results obtained in these two areas are somewhat different and will be discussed separately followed by some general conclusions.

Investigations at Linden.—*Number of broods:* Through the use of bait pans and by following the seasonal trend of infestation in the developing walnuts, it was determined that there are two broods of codling moth larvae. Depending upon the season, the first brood of caterpillars begins to enter the developing nuts from the end of April to about May 15. The preceding tabulation gives the degree of infestation on the earliest date caterpillars were found entering nuts for each year since the investigation was started.

Year	*Per Cent Infested*	*Date*
1942	No data	—
1943	2	May 7
1944	0.5	May 9
1945	0.5	May 4
1946	1.5	May 15
1947	2	May 1
1948	0.5	May 19

In all cases the caterpillars encountered were only 1 to 3 days old so that the dates given above closely approximate the beginning of the infestations. From the above tabulation it is seen that the infestation was earliest in getting started in 1947 and latest in 1948. In 1947 the season was unusually early while in 1948 it was quite late. From the information so far obtained it appears that in an average year the infestation is likely to begin sometime between May 5 and 10. It is important that this point be determined, because if optimum results are to be obtained it is necessary that control measures should be applied just prior to the appearance of an infestation.

The second brood of caterpillars makes its appearance during July and August, and most of these reach maturity before harvest which usually occurs from mid-September through the first half of October.

Experimental methods: The effectiveness of insecticides in controlling the codling moth was tested on single tree plot replicated Latin square experiments. Depending upon the experiment, the treatments were replicated from five to seven times. In some cases where a number of the new chlorinated hydrocarbon insecticides were being compared, the experimental series was removed from the arsenical treatments. This precaution was taken in order to make certain that the chlorinated hydrocarbons would have no influence upon the arsenical treatments.

Besides the individual tree plot replicated experiments, a number of treatments was applied on an experimental, commercial scale. In general these were the ones that showed the most promise in the single tree replicated experiments. A number of these treatments has been under intensive and extensive investigation for several years.

All sprays were applied to the experimental treatments at a pressure of 600

pounds with sprayers having 25-foot towers equipped for automatic spraying. The trees were large and approximately 55 gallons of material were applied per tree for each application.

In 1948 the possibility of using a speed sprayer for applying semiconcentrated sprays for codling moth control was investigated.

In order to determine the trend of infestation in the check trees as well as in the treatments, tree surveys were made from time to time during the growth of the crop. On the first surveys nuts were picked and carefully examined to see if they were infested. On later surveys the nuts were not picked unless there was some question as to whether or not they were infested. In conducting the surveys nuts were selected at random about the skirt of the trees. On each survey no less than 250 to 300 nuts were examined from each treatment and in the case of the individual tree plot replicated experiments, an equal number was observed from each tree.

Infestation in the harvested crop was determined by examining at least 400 nuts picked at random from each tree in the single tree plot replicated experiments. The 400 nut sample was weighed as was also the remainder of the crop from the tree and the total number of infested nuts per tree calculated. In the commercial blocks the per cent of infestation was determined by examining no less than 1,000 nuts per treatment. Usually 100 nuts were collected at random from each of 10 trees scattered throughout the plot.

Insecticides tested: The following were among the insecticides tested for the control of the codling moth:

1. Basic lead arsenate
2. Standard lead arsenate
3. DDT
4. DDD
5. Methoxychlor
6. Chlordan
7. (Trichloro-chloro-phenyl-phenyl-ethane)
8. Toxaphene
9. Benzene hexachloride

The rate at which the above materials were used per 100 gallons of sprays is shown in table 1.

In numerous treatments a 14 per cent dry nicotine concentrate, parathion, benzene hexachloride or tetraethyl pyrophosphate were used in combination with basic lead arsenate, standard lead arsenate, or with DDT to control the walnut aphid, *Chromaphis juglandicola* (Kalt.). The rate at which these materials were used per 100 gallons for the control of the aphid was as follows:

1. 14 per cent dry nicotine concentrate	1 pound
2. Benzene hexachloride containing 10 per cent gamma isomer	0.67 pound
3. 25 per cent parathion	0.33 pound
4. Tetraethyl pyrophosphate 20 per cent	0.25 pint

A light medium summer oil emulsion which contained 80 or 83 per cent oil was used in all treatments at the rate of approximately 0.33 gallon to the 100 gallons of spray. With most of the standard lead arsenate treatments 1 pound of a basic zinc sulphate safener was used to guard against foliage unjury.

A dry depositor was used in all of the DDT treatments and in a few of the standard lead arsenate treatments, at the rate of 0.25 to 0.33 pound per 100 gallons of spray.

In general the order of mixing the spray materials where the treatments were applied with a conventional sprayer was as follows: The dry ingredients were slurried and added to the spray tank with agitator going when $\frac{1}{3}$ to $\frac{1}{2}$ full, followed by the oil when the tank was $\frac{3}{4}$ or more full. Where nicotine dry concentrate was used, it was slurried first to prevent lumping, after which the other dry ingredients were added and the whole thoroughly mixed before pouring into the tank. In spray programs that involved the use of tetraethyl pyrophosphate, this insecticide was added just as the tank was full.

Where treatments were applied with a speed sprayer, the dry ingredients were added to the spray tank just after the water reached the half-way mark. The oil followed immediately.

Number and timing of applications: One and two spray applications have been investigated for the control of the codling moth. In order to control the first brood, an early application must be applied when the nuts are very small. Depending upon the season, it should be applied anywhere from late April to about the 10th of May. Despite the small size of the nuts at this time a single spray of an effective insecticide, if carefully applied, results in satisfactory control for the entire season. This occurs even though the second brood does

Table 1.—Relative effectiveness of various insecticides used to control the codling moth on Payne walnuts at Linden, California.

Treatment (Amount of insecticide per 100 gallons)	Per Cent Infested Nuts in the Harvested Crop			
	1945	1946	1947	1948
Check	6.77	7.05	9.24	44.25
2 sprays, 4 pounds basic lead arsenate	2.16	1.00	2.33	4.90
1 spray, 3 pounds standard lead arsenate	1.29	1.70	2.40	4.36
2 sprays, 3 pounds standard lead arsenate	0.96	0.10	1.11	—
2 sprays, 0.5 pound actual DDT. 1.5 pounds standard lead arsenate	—	0.17	—	—
1 spray, 1 pound actual DDT	0.79	0.13	1.30	—
2 sprays, 1 pound actual DDT	0.13	0.07	0.70	—
1 spray, 0.5 pound actual DDT	—	0.24	1.32	2.60
2 sprays, 0.5 pound actual DDT	—	0.00	—	—
2 sprays, 0.25 pound actual DDT	—	—	1.35	—
2 sprays, {First, 0.5 pound actual DDT / Second, 3 pounds standard lead arsenate	0.58	0.17	0.30	—
1 spray, {3 pounds standard lead arsenate plus 0.25 pound actual DDT	—	—	—	3.20
1 spray, 1 pound actual DDD	—	0.70	—	—
2 sprays, 1 pound actual DDD	—	0.10	—	—
1 spray, 1 pound actual methoxychlor	—	2.43	—	—
2 sprays, 1 pound actual methoxychlor	—	1.45	—	—
1 spray, 0.5 pound chlordan	—	13.99	—	—
1 spray, 1 pound (trichloro-chloro-phenyl-phenyl-ethane)	6.65	—	—	—
1 spray, 0.95 pound benzene hexachloride containing 18% gamma isomer	—	3.50	—	—
2 sprays, 0.95 pound benzene hexachloride containing 18% gamma isomer	—	2.25	—	—
1 spray, 2.5 pounds 40% toxaphene	—	—	6.15	—
2 sprays, 2.5 pounds 40% toxaphene	—	—	3.80	—

not infest the crop until July and later. Why a single treatment early in May should afford such protection is open to speculation. There is at least one possible explanation. This involves the fact that walnut is not the most favorable host of the codling moth, and at the time the spray is applied the stem attachment of the young nut is relatively large as compared to that of mature green nuts. Probably because walnut is not a favorable host, there is a tendency for the larvae to take a bite here and there before burrowing into the nut. By so doing, the opportunity of consuming a lethal dosage of poison, if any is present, is increased greatly over that which would occur if the larvae burrowed directly into the husk. Early in the season before the shell of the nuts begins to harden at the tip, most of the caterpillars enter the nuts at the blossom end. However, as the season advances, more and more of the caterpillars tend to enter the side and the stem end of the nuts. Later most of the caterpillars enter at the stem end, and because of the large size of the stem attachment at the time the spray was applied, it is believed that sufficient poison persists to be lethal to the larvae.

A second spray application will improve the control obtained even though a single spray in many cases results in satisfactory control. The timing of the second spray is not nearly so critical as is that for the first application. Investigations have shown that it can be applied any time from the first to about the end of June.

Results.—It is not possible to discuss the results of each of the numerous experiments conducted between 1945 to 1948 but in table 1 the important information concerning the control of the codling moth obtained for each of the years is summarized. Some slight variation occurred in experiments conducted with the same insecticide, but in no case was there more than a minor deviation from the figures given in the table. The results shown certainly indicate the relative effectiveness of the insecticides and treatments tested. Wherever a single treatment is indicated, it was applied in early May prior to the infestation by the first brood of caterpillars. Where a two spray program was followed, the first spray was applied as in the

case of the one spray treatments and the second from about June 10 to 25.

An examination of the table shows that one spray of standard lead arsenate at the rate of 3 pounds to the 100 gallons of water was about as effective as two sprays of basic lead arsenate used at the rate of 4 pounds to the 100 gallons. Despite the fact that standard lead arsenate proved to be much more effective in controlling the codling moth than basic lead arsenate, it was not widely used commercially prior to

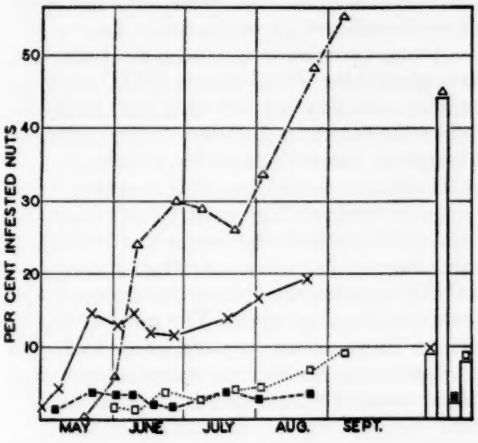

FIG. 1.—Trend of infestation during maturing of crop and infestation in harvested crop for check trees and trees receiving a single early spray of standard lead arsenate for the years 1947 and 1948. X, Check, 1947; triangles, Check 1948; solid squares, Standard lead arsenate spray 1947; open squares, Standard lead arsenate spray 1948; and histogram shows infestation in harvested crop for both years.

1947. It was believed that its use would result in foliage injury. However, it has been extensively tested with and without a safener and in no case has any injury been detected. The mass of information obtained has been so favorable that this insecticide is now generally accepted as the material to use in the codling moth spray program, and it is now used to the exclusion of basic lead arsenate.

The effectiveness of standard lead arsenate in controlling the codling moth is well illustrated in figure 1. The trend of the infestion and the amount of worminess in the harvested crop for the check trees and for a single spray of standard lead arsenate for 1947 and 1948 are shown. Although the infestation was much lighter in 1947 than in 1948, the degree of control obtained with a single spray of standard lead arsenate for the two years was proportionately about the same.

During the past two seasons, efforts were made to increase the effectiveness of the standard lead spray by adding a depositor. There is considerable evidence that the addition of a depositor increases the deposit and improves the control. To illustrate the improved control, where a depositor was added to a single spray treatment of standard lead plus safener and oil, the following may be cited. Single tree replicated plots in 1948 showed that where depositor was added the infestation in the harvested crop was 7.5 per cent while in a similar treatment where no depositor was used, the infestation was 10.75 per cent. Check trees showed an infestation of 44.25 per cent.

An examination of table 1 shows that DDT was more effective than standard lead arsenate in controlling the codling moth. A single spray of 8 ounces of actual DDT per 100 gallons of water results in better control than that obtained with a single spray of standard lead arsenate used at the rate of 3 pounds to the 100 gallons. However, DDT has resulted in an increase of other destructive pests which has made it impossible to recommend it for the control of the codling moth on walnuts. Serious increases in the population of the walnut aphid, *Chromaphis juglandicola* (Kalt.), frosted scale, *Lecanium pruinosum* Coquillett, and orchard mites (principally the European red and Pacific mite) have followed applications of DDT. Much time has been devoted to finding means of eliminating these problems and considerable progress has been made. Excellent control of the walnut aphid has been obtained where an aphicide is used in combination with DDT. Where any of the following aphicides have been used at the indicated rates per 100 gallons of spray, satisfactory control has resulted: 14 per cent dry nicotine concentrate, 1 pound; benzene hexachloride containing 10 per cent gamma isomer, 0.67 pound; 25 per cent parathion, 0.33 pound; 20 per cent tetraethyl pyrophosphate, 0.25 pint.

Present evidence indicates that the danger of the frosted scale population increasing to a dangerous level can be greatly reduced by using not more than 0.5 pound of actual DDT to the 100 gallons of spray. Little increase in the scale popu-

lation has been observed where the dosage of DDT has been reduced from 1 to 0.5 pound per 100 gallons of eater.

Orchard mites are the one problem that is still the cause of much concern. The seriousness of the problem appears to become more acute as the amount of DDT used in the spray increases. It has been greatly lessened where the actual amount of DDT per 100 gallons has been reduced from 1 to 0.5 pound. However, even at this lower dosage the problem is not entirely eliminated and under some conditions serious populations may develop. The addition of acaricides to the codling moth sprays has shown little promise in preventing a serious increase in the orchard mite population.

There is little doubt but that a serious infestation of orchard mites results in a reduced quality of the nuts. In 1946 a heavy mite infestation developed in the DDT treatments which were included in a single tree plot experiment that was replicated seven times. No orchard mite population counts were made, but mite abundance and activity were determined by observing the amount of leaf injury they caused. It was noted that the most serious injury occurred on the southeast side of the trees. In conducting surveys, next to the terminal leaflets were collected at random from the skirt of this portion of the tree for examination. On each survey 15 leaflets were examined from each tree which gave a total of 105 for each treatment. They were carefully wiped and placed in three categories according to the amount of damage sustained. The first included those that showed none to very slight feeding. The second group included leaflets which showed moderate feeding. These leaflets on close examination showed noticeable injury, but in general they were of a good green color. Severely injured leaflets were placed in group three. On these the injury had progressed to a point where much of the chlorophyl had been destroyed, and they were silvery or bronzy in appearance. Two surveys were conducted and on each of these the number of severely injured leaflets was much greater in the DDT treatments than in any of the other treatments. The per cent of severely infested leaflets encountered and the average weight per 100 apparently sound harvested nuts for each of the seven treatments are given in table 2.

From the above it is seen that the nuts weighed the least where DDT was applied, and all evidence obtained indicated that orchard mites were the primary cause of the reduction in weight.

Further evidence that mites may greatly reduce the quality of nuts was obtained in 1948. Serious mite infestations developed in some of the commercial DDT treatments that were applied with conventional sprayers. The quality of nuts from these plots as compared with that from some of the commercial standard lead arsenate treatments is given in table 3.

Table 2.—Per cent of severely mite injured leaves and weight of harvested walnuts.

Treatment Amount per 100 gallons	Per Cent Severely Injured Leaflets		Weight per 100 Nuts in Ounces
	Aug. 8	Sept. 18	
Check	12.38	21.35	33.85
2 sprays, 0.5 pound actual DDT, 1.5 pound standard lead arsenate	66.66	83.80	30.00
1 spray, 1 pound actual DDT	86.66	81.90	30.85
2 sprays, 1 pound actual DDT	81.90	92.38	31.00
2 sprays, 4 pounds basic lead arsenate	0.00	6.54	33.71
1 spray, 3 pounds standard lead arsenate	2.85	10.47	34.85
2 sprays, 3 pounds standard lead arsenate	0.00	2.85	33.00

Table 3.—Weight and quality of walnuts from different commercial plots.

Treatment[1] Amount per 100 Gallons	Weight Nuts in Ounces	Sound Nuts
Standard lead arsenate, oil, safener, parathion	32.8	73
Standard lead arsenate, oil, safener, nicotine, depositor	35.8	82
Standard lead arsenate, oil, safener, tetraethyl pyrophosphate	32.0	72
Standard lead arsenate, oil, safener, nicotine, plus 4 oz. of actual DDT	33.2	74
DDT, oil, depositor, benzene hexachloride	28.6	67
DDT, oil, depositor, nicotine	29.2	63
DDT, oil, depositor, tetraethyl pyrophosphate	30.2	56

[1] Applied May 10 and 11. Unless otherwise noted: standard lead arsenate, 3 pounds; oil, 0.33 gallon; safener, 1 pound; 25% parathion, 0.33 pound; depositor, 0.33 pound; nicotine as a 14% dry nicotine concentrate, 1 pound; 20% tetraethyl pyrophosphate, 0.25 pint; 10% gamma isomer of benzene hexachloride, 0.67 pound; and DDT, 0.5 pound actual.

From table 3, it is clearly seen that the poorest quality of nuts was obtained where DDT was used at the rate of 0.5

pound of actual material to the 100 gallons of spray. Where 0.25 pound of actual DDT was used in combination with the regular standard lead arsenate spray, the quality of the nuts compared favorably with that obtained from the treatments where standard lead was used alone. This furnishes additional evidence that where DDT is used at a low dosage the danger of an increase in orchard mites is materially reduced. There is a strong possibility that DDT at a low dosage can be used safely in combination with standard lead arsenate. Certainly such mixtures show much promise in controlling the codling moth. In 1948 a single regular standard lead arsenate spray plus 0.25 pound of actual DDT per 100 gallons reduced the infestation of codling moth in the harvested crop to 3.2 per cent as compared to 4.4 per cent where the regular standard lead arsenate spray was applied.

Where a serious infestation of the codling moth threatens, a two spray program involving DDT has shown some promise. DDT at the rate of 0.5 pound of actual material per 100 gallons is used in the first application and standard lead arsenate is used at the rate of 3 pounds per 100 gallons in the second application. This treatment has resulted in excellent control of the codling moth, and has proved to be about as effective as any treatment so far tested.

In 1948 DDT was applied with a speed sprayer. The spray mixture contained 1 pound of actual DDT per 100 gallons, and was applied at a rate of approximately 22 gallons per tree. Where applications were made with a conventional sprayer 55 gallons of a spray mixture containing 0.5 pound of actual DDT was used per tree. The amount of DDT applied per tree with the speed sprayer was 0.22 pound as compared to 0.27 pound for the conventional sprayer. Good control of the codling moth was obtained in both plots, but in contrast to the block treated with the conventional sprayer, no noticeable increase in orchard mites was observed in the speed sprayer plot. Whether the smaller amount of DDT used in the speed sprayer experiment accounts for this difference is not known.

Serious infestations of orchard mites, although associated with DDT, frequently occur where this insecticide has not been used. Because serious infestations do not occur until about midsummer or later, the addition of acaricides to the early codling moth spray appears to serve no practical purpose. In late season, attempts to control mite infestations with tetraethyl pyrophosphate applied as a smoke have been undertaken. It has been used at the rate of 1.25 pints of a 40 per cent material in a gallon of diesel oil. This amount is sufficient to treat one acre. The results obtained with a commercial machine were very promising but the investigation was too limited to justify any recommendations.

DDT has been compared with several other chlorinated hydrocarbons for the control of the codling moth. The results are given in table 1. Dichlorodiphenyl dichloroethane approaches DDT in effectiveness but it was dropped from the experimental investigations because it has apparently all the disadvantages associated with DDT, without any distinct advantages. Methoxychlor was found to be inferior to DDT, and destructive aphid populations developed where it was applied. Chlordan was found not only to be ineffective, but its use resulted in a marked increase in the codling moth infestation, which exceeded that which occurred in the unsprayed trees. This condition was observed in several localities. Toxaphene showed no promise and was ineffective even where used in a two-spray program. Trichloro-chlorophenylphenyl ethane was wholly ineffective and while benzene hexachloride showed some promise, it was less effective than standard lead arsenate or DDT.

Although the investigations on the walnut aphid are to be discussed in a separate paper, one phase in the control program will be mentioned here. The possibility of including an aphicide in the early codling moth spray has been extensively investigated for 2 years. The results have been very promising and excellent control of the walnut aphid has been obtained where the following insecticides have been used at the indicated rates per 100 gallons of spray:

14 per cent dry nicotine concentrate	1 pound
25 per cent parathion wettable powder	0.33 pound
Benzene hexachloride containing 10 per cent gamma isomer	0.67 pound
20 per cent tetraethyl pyrophosphate	0.25 pint

INVESTIGATIONS AT SAN JOSE.—Investigations at San Jose have been under

way for only two years. Experimental methods and procedure have been nearly the same as those used at Linden. The investigations have largely substantiated the findings at Linden. The main difference between the two regions is that the first brood of codling moth is later in appearing and the infestation is generally less severe at San Jose than at Linden.

The two seasons' study has shown that a single early spray of standard lead arsenate applied prior to the appearance of the first brood of codling moth is about as effective as two sprays of basic lead arsenate. A single spray containing 0.5 pound of actual DDT per 100 gallons of water has resulted in excellent control but to the present time it has not proved to be any more effective than a single spray of standard lead arsenate. The addition of a depositor to the standard lead arsenate spray appears to improve the control obtained. No foliage injury occurred in any treatment when standard lead arsenate was used. The comparative results obtained with the various treatments in regard to the control of the codling moth are given in table 4.

Table 4.—Relative effectiveness of several insecticides used to control the codling moth on Payne walnuts at San Jose, California.

Treatment (Amount of insecticide per 100 gallons)	Per Cent Infested Nuts in the Harvested Crop[1]			
	1947		1948	
	First Picking	Second Picking	First Picking	Second Picking
Check	8.55	6.00	18.9	16.6
1 spray, 4 pounds basic lead arsenate, 0.33 gal. oil	3.76	1.86	—	—
2 sprays, 4 pounds basic lead arsenate, 0.33 gal. oil	3.29	0.71	2.7	1.7
1 spray, 3 pounds standard lead arsenate, 1 pound safener, 0.33 gal. oil	1.53	1.43	—	—
1 spray, 3 pounds standard lead arsenate, no safener	—	—	3.4	3.3
1 spray, 3 pounds standard lead arsenate, oil	—	—	4.5	3.2
1 spray, 3 pounds standard lead arsenate, 1 pound safener, 0.25 pound depositor, oil	—	—	3.2	2.2
2 sprays, 3 pounds standard lead arsenate, 0.33 gal. oil	1.33	0.71	—	—
2 sprays, 3 pounds standard lead arsenate, 1 pound safener, oil	0.96	0.28	—	—
2 sprays, 3 pounds standard lead arsenate, 0.25 pound depositor, oil	—	—	1.4	0.8
1 spray, 1 pound 50% DDT wettable powder, 0.25 pound depositor, 1 pound 14% nicotine dry concentrate, 0.33 gal. oil	1.76	1.56	2.4	2.0

[1] Approximately 50 to 60 per cent of the nuts harvested at the first picking.

In order to illustrate the trend of the infestation in the developing nut crop and in the harvested crop, figure 3 has been prepared. The infestation for the check trees and for a single spray standard lead arsenate treatment for 1947 and 1948 are shown. An examination of the figure shows that the infestation started later and was much more severe in 1948 than in 1947. However, as was the case at Linden, the effectiveness of a single spray of standard lead arsenate during the past two seasons was proportionately about the same.

A peculiar type of codling moth infestation was encountered in an orchard near Campbell in the San Jose area. Interest in this orchard was stimulated by the fact that in 1946 about 20 per cent of the nuts in the harvested crop were infested. Seasonal trends in the infestation were followed in 1947 and 1948 and the results obtained are plotted in figure 4. During neither year was a first brood of codling moth encountered. It is probable that the moths developed on a crop such as apricots and these moths on emerging, finding this crop harvested, migrated to the walnuts where the second brood completed its development.

Orchard mites also proved to be a problem in the San Jose area. Some increase in the orchard mite population was observed in 1947 where trees were

treated with DDT. In 1948 the increase in the orchard mite population in the DDT treatment in a 7 by 7 individual tree replicated experiment was quite noticeable in contrast to that which occurred in the other treatments. This is well illustrated by the data in table 5, which gives the relative amount of leaf injury that occurred in the different treatments. The method used in determining injury was the same as used at Linden.

SUMMARY AND CONCLUSIONS.—Investigations conducted at Linden and San Jose have clearly demonstrated that standard lead arsenate is much more effective against the codling moth than is basic lead arsenate. A single early spray of the former at the rate of three pounds to the 100 gallons of spray, applied before the first brood of codling moth begin to enter the developing nuts, has proved to be about as effective as a two-spray program of basic lead arsenate used at the rate of 4 pounds per 100 gallons.

The addition of a basic zinc sulfate safener to the standard lead arsenate spray did not reduce the effectiveness of the material. A single spray of standard lead arsenate gives good control but everything possible should be done to increase its effectiveness. Studies during 1947 and 1948 indicated that the addition of a depositor to the spray mixture increases the deposit and improves the control obtained.

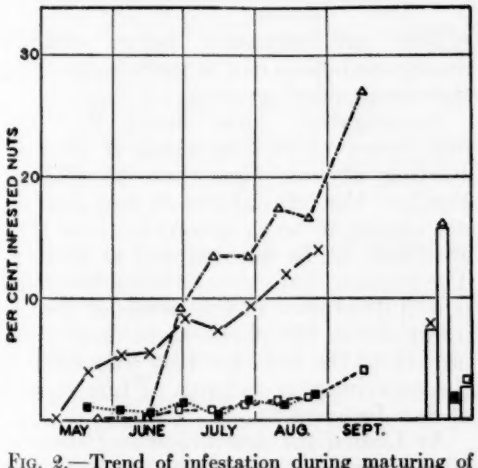

FIG. 2.—Trend of infestation during maturing of crop and infestation in harvested crop for check trees and trees receiving a single early spray of standard lead arsenate for the years 1947 and 1948. X, check 1947; triangles, check 1948; solid squares, sprayed 1947; and open squares, sprayed 1948.

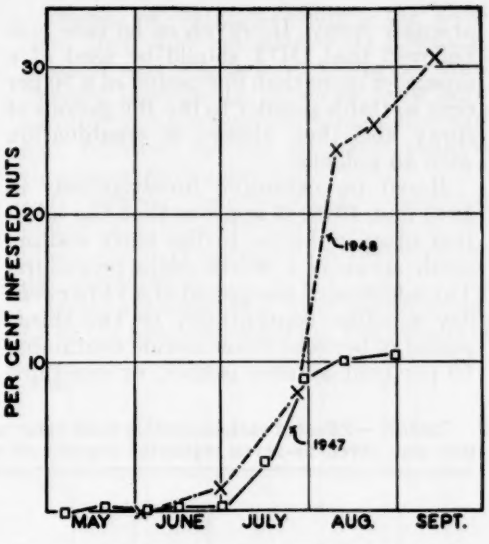

FIG. 3.—Seasonal trend of infestation in the maturing nut crop in unsprayed trees at Campbell for the years 1947 and 1948.

DDT has resulted in excellent control of the codling moth but until a highly satisfactory method for controlling mites can be developed, DDT can not safely be recommended.

At Linden an early spray containing one-half pound of actual DDT per 100 gallons of water resulted in slightly better control than that obtained with a single spray of standard lead arsenate. At San Jose the same spray programs resulted in about equal control.

Investigations have shown that 8 ounces of actual DDT per 100 gallons of spray is less likely to result in the development of a destructive orchard mite population than higher dosages. However, even at this lower amount there is some danger of serious infestations occurring.

Means of eliminating an increase in the walnut aphid population and in reducing the danger of an increase in the frosted scale populations following applications of DDT have been developed. It is hoped that a spray program may be devised whereby DDT and standard lead arsenate can be used in alternate years or alternated the same year where two sprays are necessary for satisfactory control. It is also possible that one-half pound of a 50 per cent wettable DDT powder can be added safely to the regular standard lead

arsenate spray. However, in no case is it believed that DDT should be used at a dosage of more than one pound of a 50 per cent wettable powder to the 100 gallons of spray and then always in combination with an aphicide.

Based on extensive investigations in 1947 and 1948, it appears that the addition of an aphicide to the early codling moth spray is a worth-while procedure. The addition of one pound of a 14 per cent dry nicotine concentrate, or two-thirds pound of benzene hexachloride containing 10 per cent gamma isomer, or one-third pound of 25 per cent parathion, or one-fourth pint of 20 per cent tetra ethyl pyrophosphate all resulted in very satisfactory control of the walnut aphid. Because the dry nicotine concentrate is likely to have a less adverse effect upon predators than some of the new insecticides, it probably is the safest material to recommend until the others have further stood the test of time.

There are no reports of injury from standard lead arsenate with or without a safener when used on walnuts in northern California. Because investigations have shown it to be much more effective than basic lead arsenate, it appears that unlimited recommendations for its use can be safely made.

Tests to determine the desirability of using a speed sprayer for the application of codling moth sprays were undertaken in 1948. From these preliminary investigations it appears that a desirable dosage on large trees is around 22 gallons per tree of a spray mixture containing six pounds of standard lead arsenate, or two pounds of a 50 per cent wettable DDT powder, to each 100 gallons of spray. The amount of insecticide applied per tree was 1.32 pounds of standard lead arsenate, or 0.43 pound of DDT, as compared to 1.65 pounds of standard lead arsenate or 0.55 pound of DDT applied per tree where applications were made with a conventional sprayer. However, further investigations are necessary before definite recommendations can be made concerning the use of speed sprayers.

Investigations have shown that the first brood of codling moth is later in starting at San Jose than at Linden. Further, the infestations at San Jose do not appear to be as serious as those that are likely to be encountered at Linden. The relation that exists between the areas is well illustrated in the trends of the infestations in the check trees during the growth of the nuts for 1947 and 1948 in the experimental orchards at Linden and at San Jose (see fig. 4).

At Linden the first brood in 1948 was later in getting started than in any year since the investigation was undertaken in 1942. In 1947 it was earlier than usual when 2 per cent of the nuts was found infested on May 1. In this region first brood

Table 5.—Effect of various codling moth spray programs on the orchard mite population in the single tree plot, seven-by-seven replicated experiment at San Jose.

Date of Application	Treatment and Composition per 100 Gallons of Water	Per Cent Leaflets Showing Injury					
		August 10			August 23		
		None to Light	Medium	Heavy	None to Light	Medium	Heavy
	Check	65.7	24.8	9.5	51.4	25.7	22.9
May 25 and June 29	Basic lead arsenate 4 pounds, nicotine and oil	53.3	45.7	1.0	40.0	41.9	18.1
May 25	Standard lead arsenate 3 pounds, nicotine, safener, depositor, and oil	74.3	20.0	5.7	53.3	25.7	21.0
May 25	Standard lead arsenate 3 pounds, nicotine, depositor, and oil	41.9	48.6	9.5	34.3	37.1	28.6
May 25 and June 29	Standard lead arsenate 3 pounds, nicotine, depositor, and oil	88.6	11.4	0.0	65.7	22.9	11.4
May 25	Standard lead arsenate 2 pounds, nicotine, and oil	83.6	16.2	0.0	47.6	32.4	20.0
May 25	50 per cent DDT wettable powder, 1 pound, nicotine, depositor, and oil	5.7	46.7	47.6	5.7	25.7	68.6

caterpillars do not usually begin entering nuts until May 1 to 10.

The infestation starts much later in the San Jose area where the nuts are not likely to be infested before May 15 to June 1.

The average date for applying the spray at Linden would be about May 5, while at San Jose it appears that there would be no need to apply a spray before May 20 at the earliest.

One properly applied spray in May before the first brood of caterpillars begins to enter the nuts has generally resulted in satisfactory control. A second spray applied during the second half of June will improve control, but it appears that the added benefit obtained in many instances would not justify the cost of application.

Figure 5 has been prepared to show the value of codling moth control. The average number of good nuts, infested nuts, and culls other than infested per tree that were harvested from the different treatments in the 1948 single tree plot replicated experiment at Linden are shown. The figure shows that all of the treatments out-yielded the checks by a very wide margin.

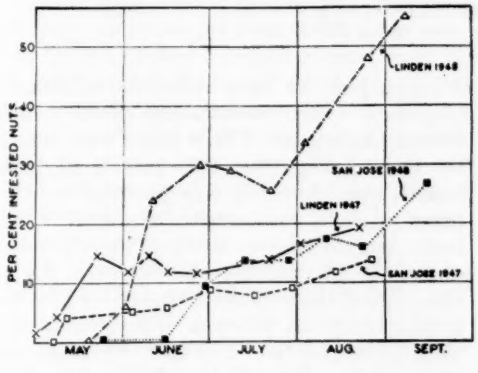

FIG. 4.—Seasonal trend of infestation in the maturing nut crop in check plots at Linden and at San Jose.

At the present time it appears that the most satisfactory spray that can be recommended for general use is as follows:

Standard lead arsenate	3 pounds
Safener (Delmo Z, a commercial basic zinc sulfate product containing 50% zinc expressed as metallic, or a similar product	1 pound
14% nicotine dry concentrate	1 pound
Light medium summer oil emulsion containing 80% to 83% oil	½ gallon
Water	100 gallons

ORDER OF MIXING.—Slurry the nicotine, then add standard lead arsenate, safener and continue to slurry. Add slurried ingredients to spray tank with agitator going when one-third to one-half full, followed by the oil when tank is three-fourths or more full.

If desired, one-fourth to one-third pound of a depositor can be added to the above spray. It should be slurried with the dry ingredients.

Other aphicides that have shown promise at the following rates per 100 gallons of spray are the following: Benzene hexachloride containing 10 per cent gamma isomer, two-thirds pound; or 25 per cent parathion wettable powder, one-third pound; or 20 per cent tetra ethyl pyrophosphate, one-fourth pint. If the latter is used it should be added to the spray tank just as it is full.

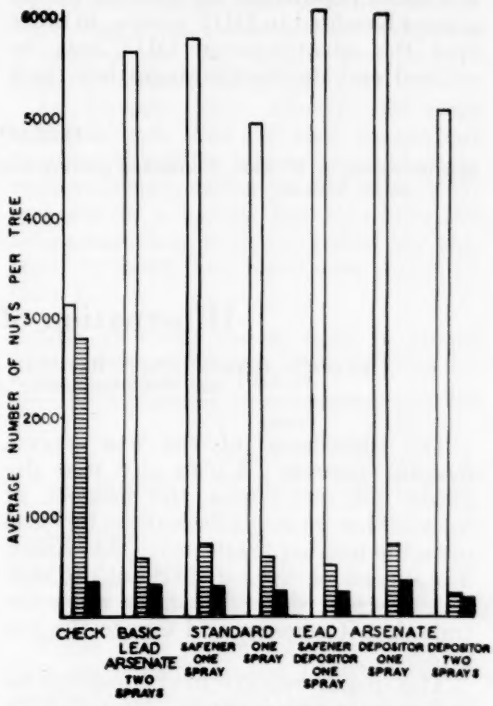

FIG. 5.—Average number of harvested nuts per tree classified as good, infested, and culls other than infested. Open bar, good; horizontal hatched bar, infested; solid bar, culls other than infested nuts.

Although not recommended, the following DDT spray has resulted in the fewest complications, and if used should not be applied to more than a limited acreage:

50% DDT wettable powder	1	pound
DDT depositor	0.33	pound
14% dry nicotine concentrate	1	pound
Light medium summer oil emulsion containing 80% to 83% oil.	0.33	gallon
Water	100	gallons

ORDER OF MIXING.—DDT and depositor slurried together, nicotine slurried, the former added to tank with agitator going when tank is one-third to one-half full, followed by the nicotine and then the oil.

To avoid a serious increase in the walnut aphid population, an aphicide should always be added to DDT sprays. In order that the advantages of DDT may be utilized and its disadvantages held to a minimum, it is recommended that if DDT is used, standard lead arsenate should be used in alternate years.

ACKNOWLEDGMENTS.—We wish to thank C. C. Anderson, Ralph Bishop, Gould Brothers, Charles Payne and H. E. Minahen for their cooperation during the course of these investigations. Thanks are also due to the several concerns which furnished insecticides. For field and laboratory assistance we wish to thank the following: Carroll Cassil, Fred Charles, Albert Foster, Clark Swanson, H. Reynolds, Edward Wegenek, D. W. Davis, O. G. Bacon, W. S. Sibray, Arthur Walz, Charles Hanson and T. W. Fisher.

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Hibernation of the Pea Weevil

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The abundance of the pea weevil, *Bruchus pisorum* (L.), in any year depends not only upon the number of weevils that go into hibernation, but also upon the number that survive the winter. The success of dusting operations to control this pest depends largely upon the time that it emerges and flies to the pea fields.

This paper reports field observations and cage studies on winter survival of the pea weevil and its emergence from hibernation, principally in eastern Washington and in northern Idaho.

WINTER MORTALITY.—The percentage of mortality sustained by the pea weevil during the winter is related to winter temperatures and to the type of material in which it hibernates. The effect of temperatures upon winter mortality of the pea weevil is influenced by snow covering. The type of hibernation material alters the effects of the temperature and the moisture conditions to which the weevil is subjected.

In Wooden Hibernation Cages. Wooden cages for hibernation studies were made to simulate conditions found in a crack in a fence post or in a wooden building—locations where weevils are often found during the winter. These cages were made by nailing together two pieces of pine board, one of which was grooved on the inner surface to a depth of about 0.125 inch. Approximately 250 pea weevils were placed in the narrow slit between them. One end of these boards was covered with a thin board. A piece of wire screen was then tacked on the other end. Through the cooperation of the United States Weather Bureau two cages were kept in Weather Bureau kiosks in 17 to 30 localities throughout Idaho during the three winters of 1933–34, 1934–35, and 1935–36.

It was found that, where the minimum winter temperatures were between −6° and −11° F., the pea weevil mortality in these cages ranged from 20 to 49 per cent and at −12° and −13° from 69 to 87 per cent. At −16° mortalities were complete in most cages. In one cage, however, the

[1] In cooperation with Agricultural Experiment Stations of Idaho, Oregon, and Washington.

The authors wish to acknowledge the work done on this project by Walter E. Peay of this Bureau, by Robert A. Fisher, Horace Shipman, and J. P. Linduska, formerly of this Bureau, and by Francis Nonini, formerly of the Idaho Agricultural Experiment Station.

mortality was 98 per cent at a minimum temperature of −18°.

During the winter of 1936–37, when the lowest temperature recorded by the Weather Bureau Station at Dayton, Wash., was −16° F., wooden hibernation cages containing weevils were set out in that locality in three ways: (1) Nailed to the base of a fence post; (2) nailed to the top of a post; and (3) fastened to the top of a post within an open-bottom wooden shelter.

From two cages in each of nine locations the average mortalities were recorded under each type of situation.

Situation of Cages	*Per Cent Mortality*
At base of post	67
On top of post, in wooden shelter	89
On top of post	98

In western Oregon, where the precipitation is greater and temperatures during the winter are higher, weevils exposed to damp conditions suffer considerable mortality due to fungus diseases, as indicated by the following examples:[2]

At Astoria, Forest Grove, and Corvallis, Oregon, in 1934 and 1935, where the rainfall from October to April ranged from 26 inches to 80 inches, and where minimum temperatures ranged from 12° to 32° F., weevil mortality in wooden cages on posts and on trees varied from 78 to 100 per cent. At the same time 1 to 6 per cent of the weevils died in cages kept in Weather Bureau thermometer shelters.

At Hood River, where the October to April rainfall was 24 inches in 1934 and 30 inches in 1935 and the lowest temperatures recorded were 27° and 4° during the two respective winters, the mortalities were as follows:

Situation of Cage	*Per Cent Mortality*	
	1934	1935
In Weather Bureau thermometer shelter	18	7
On tree trunk	32	54
On top of post	46	33
On ground, covered with trash	92	73

At Burns, Oregon, where October to April precipitation was 5 inches and where a minimum temperature of −23° F. was recorded on January 20, 1935, all weevils died in wooden cages in a shelter, on a tree, and on a post; 15 per cent survived the winter in cages on the ground covered with trash.

In Fence Posts. During the winter of 1934–35 the minimum temperature recorded by the Weather Bureau at Moscow, Idaho, was −19° F. An examination of fence posts during the following April indicated that survival of the pea weevil was much higher in posts in brushy fence rows than in posts along clean fence rows. In two very brushy fence rows 62 per cent of the 1243 weevils found in the posts were dead; in three fences clear of brush the mortality of 1359 weevils in the posts ranged from 91 to 98 per cent, averaging 94 per cent. At the same time 344 weevils were dug from beneath the bark of a ponderosa pine; 100 of these weevils were dead, a mortality of 29 per cent.

In Ground Cover. During the early spring of both 1937 and 1938 square-foot samples of various types of ground cover were collected, taken to the laboratory, and put in a berlese funnel, where the living weevils were driven out of the material by heat. The results are shown in table 1.

Table 1.—Living weevils found in various types of cover at Moscow, Idaho, following the winter of 1936–37 and 1937–38.

Type of Cover	1936–37		1937–38	
	Square-Foot Samples	Weevils Found	Square-Foot Samples	Weevils Found
Stubble and straw	6	0	32	8
Woods and grasses	36	0	77	11
Litter under brush	17	0	27	12
Duff under deciduous trees	15	2	—	—
Duff under pine trees	26	11	16	39

These data indicate that duff under pine trees was the most favorable overwintering material, and that fewer weevils survived the winter of 1936–37 than the winter of 1937–38.

The two winters were very different. The winter of 1936–37 was severe, with a minimum temperature of −30° F.; average temperatures at Moscow during December, January, and February were 5.4° below normal, and a snow cover lasted from December until March. The winter of 1937–38 was mild, with a minimum temperature of −3°; average temperatures during December, January, and February were 2.5° above normal. Snow remained on the ground for only short intervals owing to the above normal temperatures that prevailed.

[2] A. O. Larson, unpublished data.

For 4 years, 1943–46, weevils were placed in the fall in large screen cages (6 by 6 by 6 feet, and 4 by 3 by 3 feet) over four types of cover and collected as they emerged from hibernation the following spring. The average percentages of emergence from each type of cover during the 4 years were as follows: From pine trees and duff, 56; from pine duff, 40; from brush, 22; from grass, 11.

These data agree with the results obtained from examining different types of cover in 1937 and 1938 (Table 1), which indicated the same relative survival values for duff, brush, and grass.

Table 2.—Summary of weather conditions in December, January, and February. Moscow, Idaho, 1943–46.

Year	Minimum Temperature of Preceding Winter	Departure from Normal of Preceding Winter	
		Mean Temperature	Precipitation
	°F.	°F.	*Inches*
1943	−8°	−2.0°	+0.48
1944	−0°	−0.2°	−3.25
1945	+5°	+2.7°	−2.46
1946	−2°	+3.2°	+1.12

The survival in all types of cover was poorest in 1943 following the most severe winter of the four (Table 2). The next lowest survival, except in the cages around the base of pine trees, was in 1946, when the minimum temperature was −2° F., but average temperatures were highest and precipitation was greatest during the preceding winter. Perhaps the increased precipitation at abnormally high temperatures was responsible for the lighter survival in 1946, or perhaps the ground cover in the cages had become less favorable for overwintering weevils after several years of weathering.

Although weevils may overwinter in straw and debris on pea fields, experiments indicate that in the vicinity of Moscow and of Walla Walla, Washington, no weevils overwintered in shelled peas scattered on the field, but that some might live within pods until spring. A few weevils were found alive as late as March 1, 1938, in pods buried 2, 4, and 6 inches deep at Walla Walla.

No weevils have been found to survive the wet, mild winters of the Pacific Coast area in debris on the ground.

Although the pea weevil may occasionally live through two winters in stored peas, it rarely, if ever, does so out-of-doors. Large screen hibernation cages about the base of pine trees, from which the weevils were removed as they emerged during the spring and summer, were examined late in the fall, and no living weevils were found. Other cages were examined during two summers, with no evidence that any weevils survived into the second summer.

At Various Elevations. The effect of elevation on the hibernation of the pea weevil was investigated. At five elevations on Moscow Mountain wooden hibernation cages within larger wooden shelters were fastened to trees in two ways—next to the ground and 6 feet above the ground. At each location thermometers registering minimum temperatures were fastened to trees 6 feet above the ground. The mortalities of 500 weevils in each of these localities are shown in table 3.

It will be seen that (1) the highest mortalities, as well as the lowest temperatures, occurred at the lower elevations; (2) mortality was lowest at intermediate elevations around 3650 feet, and (3) mortality was highest 6 feet up on the trees during the winter of 1935–36, but at the base of the trees during the winter of 1936–37.

Temperatures at the higher elevations were lowest in 1935–36. The greatest snowfall occurred during the winter of 1936–37, and the snow remained on the ground longer that year than during the other two.

In Cold Storage. A small quantity of weevily peas taken from a supply stored in an unheated building was placed in cold storage at approximately 32° F. on November 26, 1934. On February 20, 1936, almost 15 months later, 75 of 200 adults examined were still alive, a survival of 37.5 per cent.

Other weevily peas taken from this same source were placed in storage at a temperature ranging between 9° and 18° F., averaging approximately 12°. The weevily peas were examined at weekly intervals. After 10 weeks the weevils began to show paralysis, and at the end of 20 weeks all were dead.

Submerged in Water. Pea weevils taken from peas kept in unheated storage submerged in water died in 7 days in a warm

Table 3.—Mortality of the pea weevil in wooden hibernation cages at various elevations on Moscow Mountain, Idaho, in the winter of 1934–35, 1935–36, and 1936–37.

Elevation (Feet)	Minimum Temperature (°F.)			Mortality in Per Cent					
				6 Feet up on Tree			At Base of Tree		
	34–35	35–36	36–37	34–35	35–36	36–37	34–35	35–36	36–37
2750	−19	−20	−21	100.0	100.0	100.0	—	49.1	100.0
3150	−10	−12	—	95.2	99.7	99.5	87.2	78.3	97.3
3650	−10	−14	− 8	76.7	99.1	96.4	28.9	25.5	52.4
4050	− 9	−16	−11	75.2	100.0	100.0	33.4	36.7	68.6
4750	−11	—	—	93.0	100.0	100.0	18.8	57.3	86.9

room kept at an average temperature of 78°, at an average temperature of 74° they died in 10 days. In a cold-water bath at an average temperature of 53°, 96 per cent died after 30 days. In a refrigerator at an average temperature of 32–33°, mortality was 83 per cent after 59 days, and 100 per cent after 66 days.

In Cages About Bases of Pine Trees. The emergence of the pea weevil in cages about the bases of ponderosa pine trees near Moscow has been recorded for 10 years (1938–47), and for similar cages near Walla Walla for 4 years (1938–41). These cages were of wire screen, 6 feet square and 6 feet high, with a cloth top which fitted tightly around the tree trunk. Each cage was stocked with 2500 weevils each fall, and the weevils were counted and removed as they emerged during the following spring and summer. Table 4 shows the percentage of weevils recovered from these cages.

Table 4.—Emergence of pea weevils in cages about the bases of ponderosa pine trees.

Year	Moscow, Idaho			Walla Walla, Wash.	
	Cages	Minimum Temperature in Preceding Winter	Per Cent Emergence	Cages	Per Cent Emergence
1938	2	+ 3° F.	42	2	55
1939	4	− 6°	67	4	75
1940	4	+11°	58	4	63
1941	4	+ 2°	55	4	59
1942	3	−15°	38	—	—
1943	3	− 8°	50	—	—
1944	3	0°	66	—	—
1945	3	+ 5°	50	—	—
1946	3	− 2°	57	—	—
1947	3	− 3°	68	—	—

Distribution of Weevils in Relation to Winter Weather Conditions. In winters when minimum temperatures are low enough to cause considerable mortality, the data indicate that the weevils survive best under the well-insulated bark of pine trees, under pine duff covered with snow, and at higher elevations where minimum temperatures may not be so low as at the general levels of the pea fields.

A severe winter may greatly reduce the general infestation, but in any season, whether or not it follows a severe winter, the fields nearest timbered areas are most heavily infested, and this difference is not necessarily greater following a severe winter than following a mild winter. Wakeland (1934, p. 251) stated that "in general, populations of weevils in pea fields decrease as the remoteness of the fields from timbered areas increases."

The average weevil infestations in the Idaho and Washington sections of the Paradise Creek drainage area from 1933 through 1937 are shown in table 5, together with data to indicate the type of winter preceding each season. The Idaho section was nearer the timbered area than was the Washington section. This period preceded the commercial use of insecticidal control measures which might have masked the effect of natural factors affecting population distribution. Most of the heavier infestations are found near wooded areas, and most of the lighter infestations occur away from such areas.

Table 5.—Winter weather conditions at Moscow, Idaho, and pea weevil infestions in the Paradise Creek drainage area of Washington and Idaho, 1933–1937.

Year	Weather of Preceding Winter—Departure from Normal			Per Cent Infested Peas	
	Minimum Temp.	Mean Temp. Jan. & Feb.	Precipitation Dec. to Feb.	Idaho	Wash.
	°F.	°F.	*Inches*	*Per Cent*	*Per Cent*
1933	−18°	−1.0°	+3.05	6.8	2.9
1934	+20°	+8.3°	+3.71	10.3	2.5
1935	−19°	+2.3°	−0.85	12.8	4.5
1936	−20°	−3.7°	+2.11	7.2	2.6
1937	−30°	−5.0°	+1.34	8.3	3.1

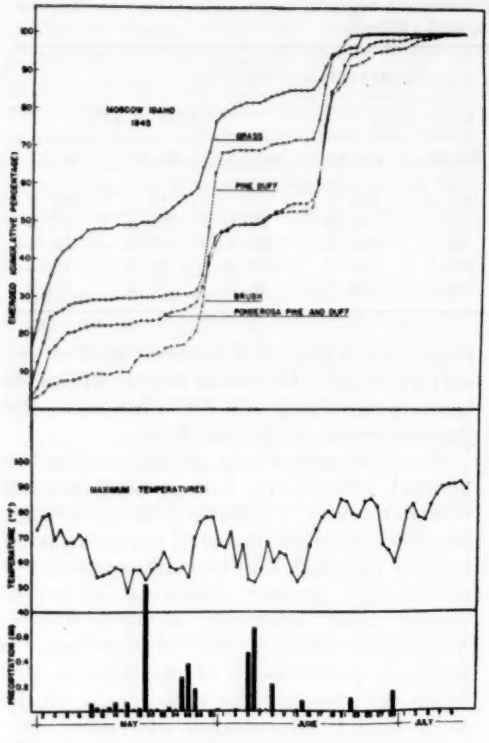

FIG. 1.—Emergence of the pea weevils in cages over different types of cover in relation to precipitation and maximum temperature. Moscow, Idaho, 1945.

The 1934 crop season followed a winter with a minimum temperature of +20° F., the other four seasons followed winters with low minimum temperatures (−18° to −30°). The infestations in the Idaho part of the Paradise Creek area (nearest timbered areas) from 1933 to 1937 ranged, respectively, from 2.3, 4.1, 2.8, 2.8, and 2.7 times the infestations in the Washington area. The difference was greatest following the mild winter of 1933–34.

Apparently factors other than temperature during the winter affect the infestations found at different distances from timbered areas. L. P. Rockwood, of the Forest Grove, laboratory, has pointed out that the high temperatures and above-normal precipitation of the winter preceding the 1934 season would favor fungus diseases which, on the Pacific coast, destroy many overwintering weevils. Another factor may be the weather conditions of the previous fall, which in 1 year might enable many weevils to travel a long distance to hibernation and in another year cause them to overwinter nearer the fields in which they developed.

EMERGENCE FROM HIBERNATION.—Emergence from hibernation was studied by frequent collections of emerged weevils from large screen cages similar to those described earlier which had been stocked with weevils the preceding fall.

In these studies the weevils were removed from the cages as they left the protective covers. There is considerable evidence, however, that during the early spring some of these weevils will return to the protective covers from time to time as the temperature falls. There are no records on the proportion of weevils which appear to return to hibernation. There is little evidence of any return to hibernation after the peas start to bloom.

From Various Types of Cover. Figure 1 shows the emergence from each of the four types of cover (grass, brush, pine duff, and pine trees and duff) over which weevils were caged in 1945.

This figure illustrates two facts that were found to be true of each of the 4 years during which these cages were examined:

1. The first emergence and the point of 50 per cent emergence occurred earliest in the cages over grass.

2. In the cages over brush or about the bases of pine trees, the weevils emerged in numbers later than in the cages over grass or pine duff.

At Different Temperatures. Emergence in the cages about the bases of pine trees was earlier at Walla Walla than at Moscow during the 4 years that cages were examined in both localities. The mean temperature for every month was higher at Walla Walla, and this is no doubt the reason for the earlier emergence.

In 1938 unseasonably warm weather brought out the first weevils in March at Walla Walla and late in April at Moscow. In the three following years emergence was later at both places, but always latest at Moscow; 10 per cent of the weevils had emerged by the following dates:

Year	*At Walla Walla*	*At Moscow*
1939	May 3	May 14
1940	April 30	May 21
1941	April 30	May 23

Figure 2 shows the weevil emergence in cages about the bases of ponderosa pine

trees at Moscow in three different years. The effect of different temperatures is very evident. It will be seen that:

1. Each peak of emergence took place when the temperature was high. When maximum temperatures were 70° F. or higher, considerable numbers of weevils emerged; when maximum temperatures were 60° or lower, few emerged.
2. Each peak of emergence is associated with a rise in temperature. The part of the temperature chart above 70° F. has been shaded to emphasize this point. In 1940, for instance, there were four emergence peaks corresponding to four periods of warmer temperatures. In 1946 maximum temperatures rose above 70° eleven times during the emergence period, with corresponding increases in weevil emergence, except during three periods of 70° to 75° temperatures between April 17 and May 10.

The observation that early spring temperatures as high as 75° F. brought out few weevils illustrates another point in connection with the effect of temperatures upon emergence. High maximum temperatures early in the season—in April and early May in the vicinity of Moscow—brought out fewer weevils than did the same maximum temperatures later in the season. The maximum temperature (80°) that brought less than 2 per cent of the weevils out of hibernation on May 3, 1946, caused over 12 per cent of the total number to emerge when the thermometer reached the same point on June 2, 1946. The 80° temperature of May 3 brought out fewer weevils than temperatures between 72° and 75° on May 17 and 21. Similar observations could be made regarding the emergence from the cages each season.

The same relationship between time of emergence and temperature was observed at Walla Walla, except that temperatures throughout the season were higher and emergence began earlier in that area.

At Different Elevations. To determine the influence of elevation on emergence one cage at Walla Walla was placed near the top of a hill at an elevation of 3500 feet—2000 feet above another in the valley. Both cages were under comparable conditions of light and shade. The emer-

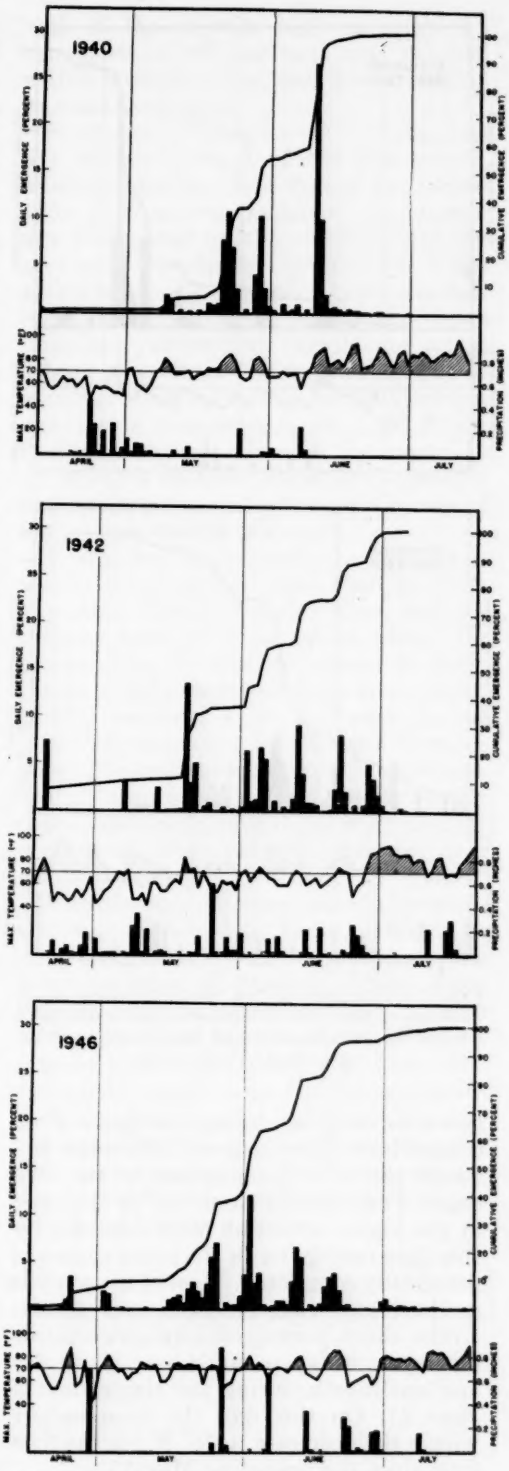

FIG. 2.—Emergence of pea weevils in cages about the bases of ponderosa pine trees in relation to precipitation and maximum temperatures. Moscow, Idaho, 1940, 1942, and 1946.

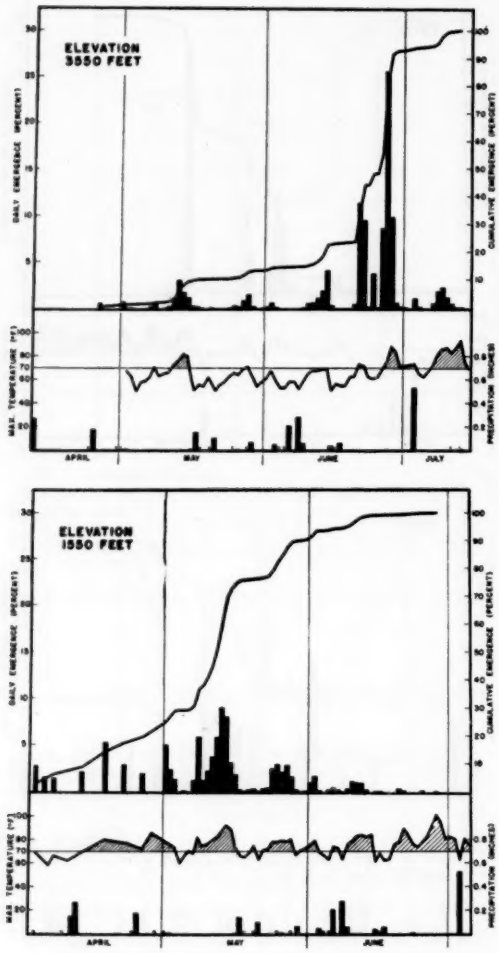

FIG. 3.—Emergence of pea weevils in cages about the bases of pine trees at high and low elevations in relation to precipitation and maximum temperatures. Walla Walla, 1939.

gence in both is charted in figure 3. A comparison shows a great difference between the weevil emergence in the two cages. Few weevils came out in the cage at the higher elevation until June 21; by this time emergence in the lower cage was practically completed. Most of the weevils in the higher cage emerged over a relatively short period of time—two-thirds during an 8-day period (June 20 to 27) and one-fourth during the single day of June 27. On this day the temperature within the cage rose to 75° F. for the first time since the preceding May 15.

Maximum temperatures recorded within the cages during the emergence period averaged approximately 12° lower at the higher than at the lower elevation.

Length of Emergence Period (*Moscow, Idaho*). The late emergence in the cage at the higher elevation helps to explain observations made in sweeping the pea fields. Throughout the pea-growing territory the movement of the pea weevil early in the season is general to the fields that are in bloom. Later, movements are not so general, being evident in some fields and not apparent in others.

The cage-emergence data would indicate that nearly all the weevils had emerged from most of the area, but that in certain parts, probably higher and cooler than in the rest, they were still coming out. This would explain why in 1938, for instance, an influx of newly emerged weevils occurred in one field in the Walla Walla area as late as July 7, when no pronounced increase in weevil populations occurred in other fields at this time.

In every year except 1943, when the season was later, weevil emergence in the cages about the bases of pine trees at Moscow began sometime after April 10 and continued until sometime in July; the entire period of emergence lasted between 10 and 12 weeks.

From 10 to 90 per cent emergence (80 per cent of the total emergence) took place over an average period of about 36 days (May 18 to June 22), ranging from 22 days in 1940 (May 21 to June 11) to 52 days in 1942 (May 8 to June 28). The widely different temperatures during these two seasons (Fig. 2) explain this variation:

1940.—Five periods of temperatures above 80° F. during the 22-day period. Average temperatures during May and June 4.5° above normal.

1942.—One day with temperatures above 80° F. during the 52-day period. Average temperatures during May and June 3° below normal.

The emergence period in 1943, which was later than in any other year, is also explained by the temperature conditions of that year. Average temperatures during May and June were below normal. The temperature rose to 80° F. on June 8 and did not rise that high again until June 28, when 5 days of temperatures around 80° raised the total emergence from 70 to above 90 per cent.

The emergence curves for the different years vary considerably. The curves for 1940 and 1942 may be cited as two extremes (Fig. 2). In 1940 most of the emergence took place during two short periods of warm weather—May 21 to 24, when temperatures were between 78° F. and 89°, and June 10 to 12, when temperatures rose to 85° and then to above 90°. In 1942 a temperature as high as 80° was reached only once (May 20) during the usual 10 to 90 per cent emergence period, emergence was much more gradual, and there were no well-defined peaks in the emergence curve.

In 1946 the period of emergence was not so long as in 1942, and the curve was somewhat smoother. Maximum daily temperatures above 70° F. during much of the period brought out the weevils steadily. There were no temperatures above 80° until June 19, after approximately 85 per cent of the weevils had already emerged.

Weevil Emergence and Control Measures. The success of insecticidal applications for weevil control is determined to some extent by the percentage of the surviving overwintering weevils that have emerged when the first peas are treated with insecticides, and the rapidity with which the remaining weevils emerge. From 1939 to 1947, inclusive, the percentage of emergence when the first peas were dusted ranged from 14 in 1941 to 98 in 1940, an average for 1939 to 1947 of 59 per cent. In 1939, 1941, 1942, and 1946 the peas bloomed early and had to be dusted at a time (June 2 to 8) when a low percentage of weevils had emerged. Continued cold weather retarded emergence, so that 90 per cent emergence was not reached for 2 or 3 weeks, making it difficult to control the weevil. During the 5 other years of this 9-year period dusting operations were begun from June 12 to 24, when at least half of the weevils had emerged. An emergence of 90 per cent was reached within 8 days or less, and weevil control was relatively easy.

SUMMARY.—Studies were conducted on the winter survival of the pea weevil, *Bruchus pisorum* (L.), during the period 1933–47 in eastern Washington and northern Idaho, and on the emergence of the surviving weevils from hibernation. Utilization was made of wooden cages simulating conditions in fence posts and wooden buildings, where the weevils are found during the winter. In such cages put in Weather Bureau kiosks, weevils seldom survived a temperature of −16° F. At this temperature, however, the mortality at the bases of fence posts was 67 per cent and under wooden shelters at the top of fence posts was 98 per cent.

It was found that weevil mortality is less in brushy fence rows than in clean ones, and that duff under pines and deciduous trees offer favorable places for hibernation. No weevils appear to overwinter within shattered peas in the field. Weevil survival over a 4-year period (1943–46) averaged 56 per cent in cages about the bases of ponderosa pines, 40 per cent in cages over pine duff, 22 per cent in cages over brush, and 11 per cent in cages over grass. Survival was greatest near wooded areas.

Weevils caged in grass emerged in numbers first, followed by those in brush, in pine duff, and about the bases of pine trees. In cages at Moscow, Idaho, from 1938 through 1947 weevil emergence began late in April and continued until July except in 1943, when it began in May. The success of weevil control with insecticides is determined to some extent by the percentage of surviving overwintering weevils that have emerged when the first peas are dusted and by the rapidity with which the remaining weevils emerge.

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A Green Fruitworm, *Orthosia hibisci*, Attacking Apricots

DEWEY J. RASKI[1] and ARTHUR D. BORDEN[2]

An unusual outbreak of larvae of a green fruitworm, *Orthosia hibisci* (Guenée),[3] occurred on apricot trees near Brentwood, California in 1943. The resulting damage to the fruit crop was the first report in California of injury caused by this species. The remarkable build-up of the larvae was short-lived and the extent of damage decreased considerably in 1944. The present observations were started in the winter of 1945–46 by which time the larvae were greatly reduced in numbers.

According to McDunnough (1938) *Orthosia hibisci* is composed of three varieties including var. *quinquefasciata* (Smith) to which the specimens observed here probably belong. However, the status of this variety and its synonym *O. proba* Smith remain to be clarified.[4]

DISTRIBUTION AND HOST RANGE.—Dyar (1904) and Barnes & McDunnough (1913) record this species from British Columbia. Mr. Crumb reports this variety of *Orthosia hibisci* is distributed from Alaska and British Columbia southward through Washington, Oregon and California and as far eastward as Idaho and Colorado. In Northern California it has been collected in at least ten counties including Alameda, Contra Costa, Lake, Marin, Monterey, Santa Clara, Santa Cruz, Sonoma, San Mateo and Trinity.

Most of the records of this species are collections made at light traps which give no information regarding hosts. According to Crosby & Mills (1935) this species in the eastern part of the United States is found along with *Graptolitha* spp. on apple, pear, poplar, soft maple, hickory and wild cherry.

The only definite host record obtained here was apricot. Several other larvae which appeared to be quite similar were collected on cherry trees but when reared were found to be *Protorthodes rufula* Grote.

LIFE HISTORY.—Larvae were collected on apricot trees near Brentwood in late March and early April of 1946 and in Berkeley, California, in early May of the same year. The larvae were found mostly in leaf buds that had not completely opened and were feeding on leaves which were lightly tied together.

Most of the larvae that were collected were more than half grown and molted only one to three times before pupating. The larvae agree closely with the descriptions by Dyar (1891) and Slingerland (1896). Slingerland illustrated and described in error the larva and pupa of this species as *Xylina laticinerea* Grote. The full-grown larva measures 30 to 38 mm. in length and is delicate but fleshy and plump (Fig. 1). The head is light green

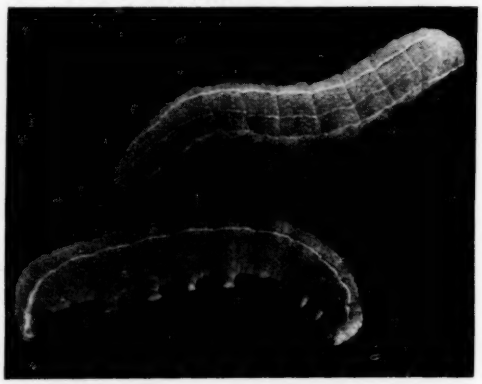

FIG. 1.—Full-grown larvae of *O. hibisci* (Gn.)

and the remainder of the body is slightly opaque light green with small cream specks throughout. A broad cream-colored dorsal line extends the length of the body. There are also two less distinct and broken, cream, subdorsal lines and two broad cream lateral lines located above the spiracles except on the second and twelfth segments where the line drops below the spiracles. The larva bears four pairs of prolegs and one pair of anal legs in addition to the three pairs of thoracic legs.

The larva turns a lighter pale yellowish-green color about the time it is ready to begin pupation. The longitudinal markings and spots are obscured by the change

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[4] Acknowledgment is made of the kind cooperation of T. N. Freeman of the Department of Agriculture, Ottawa, Canada, C. Heinrich of the United States National Museum, Washington, D. C. and S. E. Crumb of Puyallup, Washington for the identification of larvae and moths.

and the head and prothoracic shield become darker. The larvae under observation at this time began crawling actively about on the soil.

Pupation occurred between April 3 and 17 with the majority in the first week of April. The larvae collected in Berkeley pupated in late May. They seemed unable to penetrate dry soil in the laboratory but readily entered moistened soil. The smooth unlined pupal cell was made 1.5 to 2″ below the surface of the soil. The pupa is approximately 18 mm. long and 6.5 mm. at its widest point. It is dark brown in color and has as a cremaster two sharp divergent spines.

The pupae were separated into several lots and each lot subjected to different conditions of lowered temperatures in an attempt to break the diapause. All attempts were unsuccessful. The moths emerged between January 22 and April 2 of the next year and apparently one generation occurs each year.

The adult moth is a typical noctuid. In general appearance it is light brown in color with a distinct spot on each forewing and is difficult to distinguish from many other noctuids. Several moths were kept in cages in an attempt to mate them but most of the moths died within a short time. There were approximately 20 eggs deposited on the floor of the cage at one time. They were laid singly and in groups of two to five but none was viable and no larvae developed.

None of the specimens collected or reared was found to be parasitized.

DAMAGE AND CONTROL.—The larvae normally complete their development on leaves but occasionally feed on fruit. The green fruit is rarely entirely consumed. Instead small gouges may be made in many developing apricots by one larva. In heavy infestations such as occurred in the Brentwood area in the seasons 1943–1944 it is estimated that as much as 80 per cent of the fruit was damaged. These damaged apricots heal over as they continue to grow and mature but at the time of harvest are classed as culls.

Much of the damage caused by this species could be overlooked or attributed to the fruit tree leaf roller, *Tortrix argyrospila* (Walker), especially where the two occur together. However, the leaf roller feeds within tightly webbed leaves and differs markedly in coloration and in size. The leaf roller is generally smaller and may vary in color from cream to pale green but always bears a dark brown head and prothoracic shield. *Orthosia hibisci* is light green throughout. The larvae of *O. hibisci* are not as active as those of the leaf roller but do wriggle when disturbed and spin down on silken threads produced in the mouthparts.

The larvae of this species are readily controlled by most of the control measures directed against other leaf feeding pests such as the leaf roller and cutworms. Cryolite dust, 5 per cent DDT dust or 2 lbs. of 50 per cent wettable DDT per 100 gals. applied as soon as the larvae are discovered will give complete control.

DISCUSSION.—It is not possible to assign a definite explanation for the appearance of this species in such large numbers as to cause several thousand dollars damage in one season. Similarly it would be difficult to evaluate the causes for the decline of this outbreak. Control measures were promptly undertaken as soon as the outbreak was discovered but would not fully explain the disappearance of the extraordinary numbers of larvae that had developed. The species appears to be widely distributed and is probably present at least in small numbers all the time. These could easily be overlooked because of the larval feeding habits and the nature of the damage. Much more information is needed concerning its distribution, host range and variations in population from year to year before the effects of natural biological factors or the chemical controls applied could be properly analyzed to explain the phenomena observed here.

SUMMARY.—The first record in California is made of damage caused by a green fruitworm, *Orthosia hibisci* (Guenée), on apricot.

The larvae are primarily leaf feeders but also gouge small holes in green fruit resulting in culls at harvest. There is apparently one generation a year and the only definite host recorded was apricot.

Controls recommended include cryolite dust, 5 per cent DDT dust or 2 lbs. of 50 per cent wettable DDT to 100 gallons of water applied as soon as the larvae are discovered.

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Thrips Injury to Onions Grown for Seed

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Onion thrips, *Thrips tabaci* Lind, damage onion-seed crops to some extent by stunting the plants before the flowers appear, but do greater damage by attacking and destroying the pedicels of the blossoms and the flower parts. This type of injury was observed by the author in a study of the onion thrips and their relation to onion-seed production in southern California during 1945.

Other investigators have made similar observations on onions and on other plants. Sterility in oats was observed by Hewitt (1914), who described injury to the florescence caused by the grass thrips, *Anaphothrips obscurus* (Mull.). Shaw (1914), in a study of pollinators of beet flowers, stated that, when numerous, thrips attack and destroy the flower parts, but that they left the flowers after blooming had ceased. Annand (1926) in a discussion of Thysanoptera and the pollination of flowers, concluded that, in addition to acting as pollinators, thrips blight the flowers they visit by destroying the tender parts of the bloom. Pearson (1930) recorded that "Extensive feeding [by onion thrips] on the pedicel of the young bud may cut off the food supply."

METHODS OF INVESTIGATION.—Seven onion-seed fields were under observation; three in the Coachella Valley of the White Globe variety including one at Indio and two at Thermal (the George Beach field and the Santana Brothers field), one at Yucaipa of White Globe and Texas Grano varieties, one at Banning of White Globe, and one each at Alhambra and San Fernando of the Sweet Spanish variety. The Alhambra planting was a small plot 30 by 100 feet arranged especially for this study. Protected and unprotected plants were observed in all fields except those at Banning and San Fernando.

Two types of protection from thrips attack were used. To protect the plants as well as the flowers, 10 per cent DDT was dusted weekly on plots in each of the five fields. The fields at Yucaipa and Indio were a part of the regular thrips-control program; treatments were replicated in randomized block designs. The two fields at Thermal were untreated except for 4 plots, 12 by 200 feet, which were dusted with 5 and 10 per cent DDT. The DDT was first applied when the flower stalks were 6 to 12 inches high, and dustings were continued until 25 to 50 per cent of the heads, or umbels, had set seed. This treatment required 5 to 6 applications.

To protect the flowers themselves, paper bags were placed over 10 unopened umbels in each of 2 fields at Thermal, and Cellophane bags over 50 unopened umbels at Alhambra. The bags were left in place until the seed on the surrounding plants had set.

To determine how thrips reach the flowers, at Alhambra tanglefoot bands were placed around the stalks of 10 umbels near the umbel before the bracts had opened. The number of thrips per flower umbel was compared in protected and unprotected umbels at blossoming time.

Observations were made in the two fields at Thermal and the one at Alhambra at 7- and 14-day intervals from the time the flower stalks were 6 inches high until the seed was mature. Thrips were col-

lected to determine the species involved, frequent comparisons were made of the number of thrips present, and numerous photographs were taken to show various stages of plant development and the relation of thrips to plant injury. In the two Thermal fields, the weights of mature seed per 400 heads were compared in dusted and undusted plots.

DAMAGE TO THE PLANTS.—When seed stalks appear, onion thrips are usually numerous in the axles of the leaves, and as the plant grows more and more thrips attack the stalks. On an average, 65 to 90 thrips per stalk and 120 to 180 thrips per leaf of the same plant were common in the Coachella Valley. Large thrips populations during the development of the seed stalks caused curvature and stunting. Stunting was obvious when undusted and dusted plants were compared. Dusted plants appeared clean and bright green, whereas undusted ones were yellow green, misshapen, and unthrifty.

In 3 Coachella Valley fields 470 stalks from undusted plants averaged 23 to 25 inches in height, and 455 stalks from dusted plants were 27 to 31 inches. In addition to the plants being stunted, the flower umbels of undusted plants were reduced in size. Seed umbels of undusted plants in the Alhambra planting ranged from 2.5 to 3 inches in diameter, whereas those of plants dusted with DDT were 3 to 4 inches across.

HOW THRIPS REACH THE FLOWERS.—Thrips entered the flower umbels as soon as the first bracts opened, and built up in larger numbers than could be explained by thrips populations on the stalks. This observation was first made at Thermal and at Banning. The number of thrips per umbel in the Santana Brothers field at Thermal on April 17, when 4 per cent of the umbels had opened, ranged from 128 to 312, with a mean of 238. Previous counts had indicated an average of 160 thrips per individual plant. This increase in thrips abundance was found to be due partly to western flower thrips, *Frankliniella occidentalis* (Perg.), that had migrated from surrounding vegetation, and partly to onion thrips that had flown there.

At Banning, however, two-thirds of the thrips in flower umbels after most of them had opened were flower thrips and one-third were onion thrips. At Yucaipa as many as 95 per cent of the thrips in umbels at the edge of the field nearest wild flowers were flower thrips, but at the edge farthest from wild plants the number was as low as 1 per cent. At Alhambra, where flower thrips were not common in the flower umbels, tanglefoot barriers around the stalks accounted for only 59 per cent of the onion thrips in the umbels. In 10 umbels protected with stalk barriers the number of thrips ranged from 27 to 56 in each, with a mean of 40.6, whereas in 10 comparable unprotected umbels the number ranged from 40 to 147 thrips in each, with a mean of 99.4. The number of thrips in unprotected umbels must have been increased by the thrips that flew from other plants.

NATURE OF THRIPS FEEDING.—The nature of thrips feeding, which causes a characteristic necrosis of plant cells, has been the subject of considerable discussion. Wardle & Simpson (1927) discussed the feeding habits of onion thrips in relation to cotton leaf injury. They described the punctures made by onion thrips as gashes made by pickaxe-like movements of the single mandible. Observations of larvae and adults feeding on the onion leaf, made under 30- and 60-diameter magnifications, did not entirely verify their description. The mouth cone was merely placed against the leaf and the piercing organs were inserted. Movements during this piercing operation were similar to those of other sucking insects, and no pickaxe-like movements were observed. The mouth cone was moved from place to place in much the same manner as that of a grazing animal. Many punctures were made in a few minutes. Under 60-diameter magnification the punctures could be distinguished as numerous round openings in the center of an area that at first was dark but later appeared to be silver. On young onion leaves these punctures were similar to leaf stomata, but differed in that stomata form a regular pattern and are slitlike openings, whereas punctures made by thrips form an irregular pattern and are nearly circular. On mature onion leaves stomata are much larger and are easily distinguished from thrips punctures.

A pattern of feeding by the citrus thrips, *Scirtothrips citri* (Moult.), was recorded by Barnhard (1943), who showed that they feed by puncturing alone. Sakimura & Carter (1934) observed that,

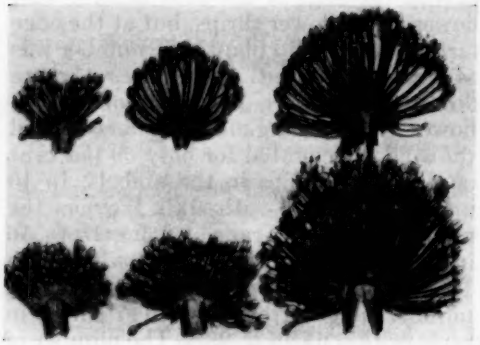

FIG. 1.—Vertical sections of equal thickness through dusted (lower) and and undusted (upper) onion-flower umbels at three stages of development, from the first opening of the enclosing bracts to blossoming. ×1

when onion thrips were fed through fish-skin membranes, no typical feeding macerations developed on the membranes and that there were no leaks, an indication that feeding had occurred through very fine punctures.

The function of the paired piercing organs, or maxillary setae, was not observed, but the nature of the punctures and the destruction of plant cells beneath the epidermis suggest that these organs were inserted and used to break down and prepare cell contents for reception by the hollow mandible.

A few punctures do not cause sufficient leaf injury to produce a noticeable silvering, but when hundreds of punctures are made close together, a silvery or gray spot appears. This silvery effect is not due to thrips injury to the epidermis, but is merely the natural appearance of the epidermis when cell material beneath has been removed.

INJURY TO FLOWER PEDICELS.—The flower umbel, with its hundreds of flowers borne on long slender pedicels, is the part of the plant most vulnerable to thrips attack. At the first opening of the bracts, which tightly enclose the immature umbel, the flower pedicels and the developing flower buds are subject to injury by thrips and many buds are destroyed before they are fully formed. As the pedicels lengthen to form the complete inflorescence, the number of thrips increases. The resulting damage ranges from slight injury of the pedicels to complete destruction (Fig. 1). Slight injury consists of small, silvery, shrunken areas, whereas more severe injury may range from the shriveling of small sections, causing a pinched-off condition, to the collapse of the entire pedicel (Fig. 2). The number of buds that produce seed is often sharply reduced in this way. In Table 1 is summarized the number of blossom buds and thrips per umbel on 15 undusted umbels compared with the number on 15 umbels from plants dusted with 10 per cent DDT. There were 54 per cent fewer buds in undusted than in dusted umbels.

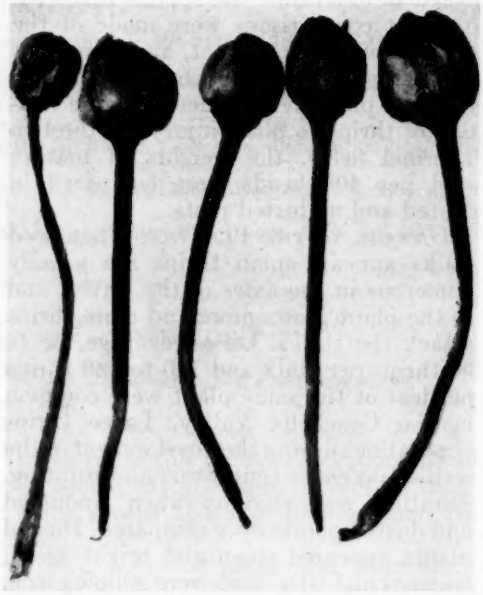

FIG. 2.—Onion-flower buds showing damage to the pedicels caused by the onion thrips.

When the onion flowers open, the thrips attack the flower parts before they have formed completely (Fig. 3). The filaments supporting the anthers and the anthers themselves are most severely injured. On an average eight thrips were counted per damaged flower (Fig. 3). Most of the thrips were the western

Table 1.—Average number of blossom buds and thrips per umbel in five undusted and five DDT-dusted onion flower umbels in each of three stages of development. Alhambra, Calif., 1945.

Stage of Development	On Undusted Umbels		On DDT-dusted Umbels	
	Blossom Buds	Thrips	Blossom Buds	Thrips
First opening	300	82	721	6
Midpoint	439	168	980	6
Blossoming	504	187	1105	10

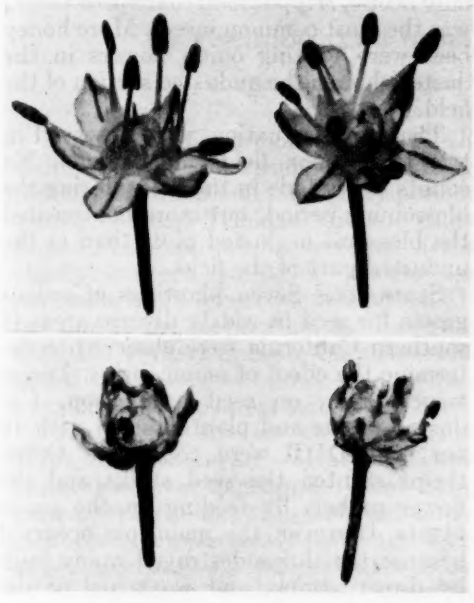

FIG. 3.—Onion blossoms from dusted (upper) and undusted (lower) onion plants.

flower thrips. The filaments are attacked and destroyed in the same manner as the flower pedicels. This injury commonly prevents the anthers from developing, or the anthers themselves may be so badly damaged that little or no pollen is produced. There appears to be no difference between the onion thrips and the western flower thrips in the nature of their injury to onion flowers However, since the western flower thrips often enter onion-seed fields in large numbers at blossoming time, they may damage more flowers than the onion thrips.

The styles and ovaries of the many flowers examined seemed to be scarred by thrips feeding, but no injury to the ovaries or to the seed capsules was severe enough to cause damage. The seed capsules were

FIG. 4.—Vertical sections through onion-seed umbels from Alhambra, Calif., after the seed capsules had formed.

much less attractive to thrips than were the flowers, and after blooming had ceased the thrips population in the umbels decreased and any remaining thrips were among the pedicels at their base. Thrips continued to attack these slender stalks after the seed had formed and caused a certain amount of injury (Fig. 4), but they gradually left as the maturing seeds became less attractive.

SEED YIELD IN DUSTED AND UNDUSTED ONION-SEED PLOTS.—Loss of seed due to thrips injury is evident when the weights of seed from dusted and undusted umbels are compared.

DDT was effective in reducing the thrips populations in the flower umbels in all five fields, but at Indio there were 15

Table 2.—Weights of onion seed from samples of 100 umbels collected from undusted plots and from plots dusted with DDT. Thermal, Calif., 1945.

CONCENTRATION OF DDT (PER CENT)	UNDUSTED PLOTS		DUSTED PLOTS	
	Per Umbel	Per Acre	Per Umbel	Per Acre
	Ounce	*Pounds*	*Ounce*	*Pounds*
		George Beach Field		
10	0.050	248	0.075	371
10	.048	238	.088	440
5	.042	207	.068	337
5	.048	238	.062	307
Mean	.047	233	.073	361
		Santana Brothers Field		
10	0.060	297	0.062	307
10	.045	223	.058	287
5	.045	223	.055	272
5	.047	228	.048	238
Mean	.049	242	.056	277

to 30 per cent as many thrips in protected umbels as in unprotected ones by the time another treatment was due. At Alhambra, where a larger proportion of the onion plants were treated, there were only 2 per cent as many thrips on the protected plants as on the unprotected.

Seed yield in DDT-treated plots at Indio averaged 0.048 ounce per umbel. Likewise in two fields at Thermal the yield of onion seed was greater in plots dusted with DDT than in undusted plots (Table 2). The weight of seed per umbel in the treated plots was therefore as great as, or greater than, that in the untreated plots. Jones and Rosa (1928) indicate that 200 pounds of seed per acre is a fair yield for white onions.

Others means of protecting onion umbels, such as paper and Cellophane bags, were effective in keeping out thrips as well as other pollinators. Consequently, no seed was produced.

INSECTS OBSERVED VISITING ONION FLOWERS.—Because of the possibility that DDT might kill or repel insect pollinators visiting onion flowers and thereby reduce the seed yield, a few observations were made to compare the numbers of insects visiting treated and untreated onion blossoms. The treated flowers were in regular thrips control plots in the Richards field at Indio, and the untreated flowers were in the untreated portion of the same field. Ten per cent DDT at the rate of 30 pounds per acre was applied at weekly intervals to some of the plots and at biweekly intervals to others from March 20 to April 25. The insects were counted on the flowers of three onion rows 300 feet long at two locations in each portion of the field. Counts were made at two stages of the blossoming period. The observer made counts while walking slowly through the field, and only those species seen more than twice were included (Table 3). The honey bee was the most common pollinator, other than thrips, and the convergent lady beetle, *Hippodamia convergens* Guer., was the most common insect. More honey bees were visiting onion flowers in the dusted than in the undusted section of the field.

Table 3.—Number of insects visiting dusted and undusted onion flowers at two stages of the blossoming period. Richards Field, Indio, Calif. 1945.

INSECTS	41 PER CENT OF HEADS IN BLOOM (APRIL 24)		78 PER CENT OF HEADS IN BLOOM (MAY 1)	
	Undusted	Dusted	Undusted	Dusted
Diptera	23	8	5	5
Honey bees	2	9	27	66
Wild bees	2	0	9	4
Lady beetles	46	9	246	70

The same situation was observed in two later onion fields at Thermal. No counts were made in the fields during the blossoming period, but more bees visited the blossoms in dusted plots than in the undusted part of the field.

SUMMARY.—Seven plantings of onions grown for seed in widely diverse areas of southern California were observed to determine the effect of onion thrips, *Thrips tabaci* Lind., on seed production. Undusted plants and plants dusted with 10 per cent DDT were compared. Onion thrips stunted the seed stalks and the flower umbels by feeding on the onion plants. However, the main loss occurred because the thrips destroyed many buds by direct attack, and weakened or destroyed the flowers by damaging the pedicels so that seeds were prevented from being formed. Onion thrips feed by puncturing plant cells beneath the epidermal layer and sucking up the cell contents. Gashing was not observed and newly injured leaves revealed a distinctive pattern of punctures. The western flower thrips, *Frankliniella occidentalis* (Perg.), as well as the onion thrips, commonly infested onion umbels and flowers, and caused a similar type of injury. The use of DDT to protect onion blossoms from thrips did not exclude insect pollinators to the extent of reducing seed production. Honey bees visited dusted flowers in greater numbers than they did undusted flowers.

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Insect Notes from South America with Special Reference to *Pseudococcus brevipes* and Mealybug Wilt[1]

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During the last 6 months of 1946, the writer had the opportunity to visit many sections of Brazil and for shorter periods, Dutch Guiana, Trinidad and the Canal Zone. The observations recorded herein chiefly concern pineapple insects and particularly *Pseudococcus brevipes* (CKl.) but due to the cooperation received from scientific workers in those countries some useful data were obtained on other insects of economic importance.[2]

Pseudococcus brevipes AND MEALYBUG WILT OF PINEAPPLE.—Mealybugs were found wherever pineapples were being grown, whether in old established settlements or in remote native plantings. They were universally *P. brevipes* but whether all of one strain is doubtful. Mealybug wilt incidence followed the same pattern as seen elsewhere throughout the pineapple growing areas of the world (Carter 1942), that is, rare in temporary plantings in virgin soil, more common in established pineapple growing districts but nowhere as severe as in Hawaii where pineapples are grown continuously on the same land with only short fallow periods between cycles. Observations in several districts in Brazil will serve to emphasize some of the more important ecological factors which seem to account for the differences observed.

Mealybugs on pineapple were normally located on the base leaves of the plant under the surface of the soil. Large colonies on the median leaves were very rare: the few cases found were completely covered with a soil mound built by ants *Solenopsis*. Colonies on fruit were also extremely small except in rare cases. It is clear that the habit of the mealybug found generally on cultivated pineapple plants in Brazil differs from those of the two strains known in Hawaii. The greenspotting strain in Hawaii is primarily a bisexual form feeding on the upper portions of the plant, the non-greenspotting, a parthenogenetic form feeding on base leaves and sub-surface. However, males were frequently found among the soil covered colonies in Brazil and sparse greenspotting was found generally on the leaves of these plants.

The typical condition therefore was of a large basal leaf sub-surface mealy bug colony with only small upper leaf colonies and scattered green spots. Every plant pulled up in the Boituva-Tatui area in the State of Sao Paulo was infested with base leaf colonies and I was informed that in summer this condition was universal, with very large colonies of mealybugs.

The small leaf colonies could be accounted for on the following grounds, probably all contributing. One was the season, it being winter with night temperatures which in Hawaii would be considered limiting to large colonies. Another is the probability that the strain of *Pseudococcus brevipes* there is only casually an aerial form and, thirdly, control of leaf colonies by parasites. This last will be discussed later under the topic of biological control.

Since leaf colonies were so small it followed that fruit colones were also small. Colonies of mealybugs on the slips, which on the commercial variety surround the fruit in a dense mass, were almost nonexistent on the leaves but in one count that was made every slip had a few mealybugs on the base of the slip near the attachment to the fruit peduncle. Planting of such slips does of course insure the infestation of new plantings.

Ants, universally associated with *Pseudococcus brevipes* are common in the Tatui fields. In a single morning's observation at least five species of ants were observed, but no one species appeared to dominate as is the case when *Pheidole*, *Solenopsis* or crazy ants are in attendance. These species were not-observed.

The occurrence of mealybug wilt in this area is of considerable interest. The district is an old settlement and pineapples have been grown there for at least 50 years with planting material passed from farm to farm. With the universal in-

[1] Published with the approval of the Director as Technical Paper No. 187 of the Pineapple Research Institute, University of Hawaii.

[2] The writer was in Brazil as visiting professor at the Escola Nacional de Agronomia in Rio and later served as consultant for the Cocoa Research Institute at Bahia and the Instituto de Pesquisas Agronomicas at Recife. The writer's visit to this country was greatly facilitated by the kindness of many people, but he is particularly indebted to Prof. Angelo Moreira da Costa Lima.

festation of this material as both observed and attested to by Instituto Biologico workers the incidence of wilt appears to be determined by the ecological factors responsible for the occasional movement of mealybugs from the base leaves of the plants up to the proximal green tissue of the leaves. Experience in Hawaii has shown this area to be the feeding point necessary if wilt is to ensue. Parasites and predators eliminate these leaf colonies and scattered green spots are frequently the only evidence that mealybugs have fed on the leaves.

Occasional other evidence, particularly in the Boituva area, was seen in the presence of the symptom described as mealybug stripe (Carter 1944). This symptom, which is localized, results from the feeding of a fair sized colony of mealybugs and is characterized by chlorotic streaks over a few inches of the leaf length and generally on several leaves of one plant. The presence of this symptom is strong circumstantial evidence for the occurrence of occasional mass movement of mealybugs from sub-surface colonies.

Rare cases were seen where mealybug colonies on newly planted slips were so large that growth had not started or had stopped, but this was the exception. Actually, considering the widespread occurrence of mealybugs, wilt was not common. The practice of planting on virgin land would undoubtedly reduce susceptibility to mealybug wilt and biotic factors were certainly reducing leaf colonies to a minimum.

A 12-month-old planting next to an older ratoon planting presented a picture very similar to what might be encountered in Hawaii without control measures except that the colonies were predominantly base leaf. The newer planting was very heavily infested. There were huge base leaf subterranean mealybug colonies and many plants had either not started or had wilted shortly after. There were many small spots within the field where growing plants in groups of 2 or 3 were showing typical first to fourth stage wilt symptoms.

In the vicinity of Rio de Janeiro, the pineapple plants growing on two experiment station grounds were largely derived from a cross between Pernambuco and Rondon. They were thin, leathery and tough leaved.

Wilt symptoms on these plants, which had large sub-soil base leaf colonies of mealybugs were mostly on the outer whorls of leaves with little of the downward flexing of the whole leaf typical of wilt in the more succulent varieties.

An experiment at the Deodora Experiment Station near Rio was conducted in which young pineapple plants were infested with gross colonies from nearby older pineapple plants. The test plants were first examined critically for mealybugs both on the upper and sub-surface leaves and found to be free. Two infestations were made but when the second was applied, examination revealed that the first colony had moved to sub-surface positions on the base leaves with only an occasional mealybug left in the center of the plant and even these were soil covered. A second infestation was applied a month after the first. Two months after the first infestation marked growth reduction of the infested plants was evident and first stage wilt symptoms *i.e.* color changes to darker red and downward reflexing of leaf margins. The median leaves were greenspotted but the colony as a whole was sub-surface.

Pernambuco variety is rarely grown in the south of Brazil but on one farm where the typical variety of the area, Yellow Paulista, was being grown alongside Pernambuco, the former was evidently more susceptible to wilt than was the latter under the conditions of the local environment.

On small farms in the vicinity of Rio, the variety *Ananas sativus* var *pyramidalii*, showed typical wilt in a situation where scattered mealybug colonies were attended by a species of *Prenolepis*. This species of ant was active and a wide ranger in contrast to *Solenopsis* which tends to concentrate its nest around a single plant and literally encloses the mealybug colony in a huge soil shelter.

Observations in the state of Pernambuco covered the extremely varied local conditions found in that state, from the coastal strip back to the hinterland where the only pineapples grown were in an irrigated experiment station grounds. In that state the typical variety is the Pernambuco, known locally as White Paulista. This state, being more tropical and more closely approximating Hawaiian conditions with respect to climate it was

expected that wilt incidence might be greater than in the temperate South in spite of the fact that the variety grown is a relatively resistant variety. This proved to be true. The mealybug colonies, frequently very large, were however typically sub-surface on base leaves, leaf colonies were small and only rarely were more than a few mealbyugs found on slips or on fruit.

Greenspotting was general but often there were few if any mealybugs on the greenspotted leaves, indicating only occasional movement from base leaf colonies.

The relationship between susseptibility and virgin plantings was once more strongly evident. At the experiment station at Tapirema, north of Recife, there was a small field in which wilt was much more evident on one half than on the other. Inquiry elicited the fact that the portion of the field showing much more wilt was an old planted area, while the section of the same field showing practically no wilt was a virgin area cleared of forest just prior to planting. Since the whole field had been prepared for planting at the same time and had been planted with the same lot of planting material, the difference between wilt incidence in the two sections was clearly significant.

It was in the state of Pernambuco that exceptions to the almost universal freedom from wilt of virgin plantings were noted. In the grounds of the military school at Aldeia near the city of Recife, there were huge colonies of *Solenopsis* attended mealybugs at one end of a planting in poor and sandy virgin soil. There were many typically wilted plants in this area. At Goiana near the northern border of the State, a first planting was examined, again on poor sandy soil in which wilt was serious. Mealybug colonies, *Solenopsis* attended, were very large.

These observations indicate that the normal freedom from wilt in virgin soil can be lost if the soil is poor and mealybug colonies large and uncontrolled.

The recent finding that "native" *Ananus comosus* is a mycorrhizae is of interest in this connection (Pittendrigh 1948). The freedom from wilt in rich organic virgin soils has been abundantly demonstrated. The possible relationship of mycorrhiza to this phenomenon is worthy of some attention.

In Belem in the state of Para, a few typically wilted plants were seen. In this area mealybug colonies were rather rare, although when found, were large on both upper and basal leaves with greenspots numerous. From this section a short visit was paid to Dutch Guiana. There, wilt was typical and greenspotting the rule in all the sections visited, which were within easy distance of the town of Paramaribo. These were all in small native plantings growing in a weak impoverished soil which appeared to be almost pure quartz sand.

BIOLOGICAL CONTROL FACTORS.—It would be expected that in the native home of the pineapple plant there would be well developed biological control complexes. This is true but economic control is not achieved. *Anagyrus* (Gahan 1948) was well represented in collections made throughout the entire area visited. *Hambletonia pseudoccina* was seen only sparingly in the Sao Paulo area and once at St. Augustine in Trinidad. This confirms the experience of C. T. Schmidt who collected during the season Nov.–March of 1936 and 1937.

The most interesting parasite encountered was *Pseudaphycus* sp. taken in the district of Tatui in the state of Sao Paulo, in considerable numbers. This extremely active and efficient insect was found parasitizing mealybugs on the aerial portions, leaves and inflorescences of the plant. It was never found on colonies of mealybugs which were clustered on the base leaves below the soil surface, but upper leaf colonies were so heavily parasitized that large colonies on this portion of the plant were rare. It was not uncommon to find inflorescences with only one or two mealybugs and these parasitized. The life cycle of this insect varies from 14 to 20 days, and as many as 6 adults may emerge from a single mummified mealybug. The experience with this insect in Hawaii has proved most interesting. In Hawaii it has not yet been shown to successfully parasitize any but the non-greenspotting strain of *Pseudococcus brevipes*, yet in Sao Paulo the leaves of infested plants were greenspotted, lightly it is true compared with typical Hawaiian conditions, but nevertheless typically. Furthermore, males were found associated with these colonies which further separates them from the non-greenspotting

strain in Hawaii (Ito 1938). It has not yet been possible to examine the long series of symbiont preparations made by the writer throughout the area, but on the basis of parasitism, either the Sao Paulo colonies were mixed or the green-spotting strains of Hawaii and Sao Paulo are not identical. The activity of this parasite probably helps to account for the complete absence of heavily mealybug infested slips which grow off the fruit stem just below the fruit. *Pseudaphycus* was quite localized however. *Anagyrus*, while never so plentiful was nevertheless the most frequently encountered parasite.

Predators, principally coccinellids were nearly always present and attacked the sub-surface colonies, but never in any great numbers. Actually, biological control factors can, on the whole, be considered minor as far as reduction of colony size is concerned when the colony throughout the plant was taken as a whole.

These observations are valid only for the dry winter season. What the effect of hot wet weather in the summer would be on entomogenous fungi is not known but as has been mentioned, mealybug colonies in the state of Sao Paulo were reported to the writer as being even more extensive than in the winter.

It is the opinion of the writer that biological control of mealybugs must be supported by measures to achieve ant control because in the natural state *Pseudococcus brevipes* and ants of one species or another are always found together.

OTHER PINEAPPLE INSECTS.—*Melanaspis bromeliae* (Leonard) (=*smilax* Comstockii). This dark brown circular scale insect was found at Deodoro, near Rio de Janeiro. The insect was associated with a curious and previously undescribed spotting of the leaf. Underneath the scale the color of the leaf is darker than the normal color. This darker green spot is circular. As a halo round this spot, is a much larger chlorotic ring. The development of the dark central ring begins shortly after the establishment of the crawler on the leaf. The chlorotic ring develops later and becomes depressed, leaving the green center as an elevated island.

Thecla sp. is the most serious economic insect of pineapple in the southern part of Brazil. Most of the fruits seen were affected although damage was reported to be seasonal. In addition to leaving malformed fruit, some of which resembled cripple (Linford 1935), and large masses of protruding jelly, the larva also functions as a leaf miner, leaving only the upper and lower epidermis. In the Tatui area, red buds and young fruit were universally infested with *Thecla* eggs which are quite large and glistening white. Spray operations were being attempted using a spray which contained 350 grams of lead arsenate to 100 liters of water. Three sprays were being applied during the red bud and early fruiting period.

Paradiaphorus crenatus (Billberg). This large weevil was fairly common in Sao Paulo state. Seriously affected plants stand out because of their reddened color and partly wilted appearance. The insest bores into the stump apparently at ground surface. Affected plants are red all over and can be dislodged very easily at that stage because the connection between the stump and the underground portion is almost gone. The borer bores up the stem for a considerable distance but no cases were seen of affected fruiting plants, so whether the larvae ever reach the fruit could not be determined. The few larvae seen, even those apparently almost full grown, were still in the thick portion of the stump.

Termites boring into the stumps of living plants gave the plants a wilting appearance similar to that observed in weevil infested plants and this condition was seen on several occasions in the Tatui area but always limited to scattered isolated plants.

A large lepidopterous borer, *Castnia licus* Drury, was observed in the area around Recife, Pernambuco. The larva is approximately 3 inches long when full grown. It bores into the stem and up into the fruit peduncle. The moth has about a 5-inch spread. The insect is well known but never epidemic according to reports.

In the state of Bahia, a membracid was found in a large colony at the base of a pineapple fruit in association with ants and *Pseudococcus brevipes*.

YELLOW SPOT: (Tomato Spotted Wilt). Although this virus is well known on tomato and tobacco in Brazil, no instance was seen of its occurrence on pineapple. This may have been due to the

season—it was towards the end of the dry-winter—because resistance tests seen by the writer at Campinas, state of Sao Paulo, were inconclusive due to the very low incidence of disease in even the susceptible varieties of tomato being used in the tests.

NOTES FROM DUTCH GUIANA.—Lelydorp cannery area. A bug, *Athanmastus lactus* Merr. was found on a pineapple plant which had the inner whorls redened. On the leaves were large numbers of short straight white lines. This insect is reported to be common on pineapple in the area. It is also referred to in the Annual Report of the Department of Agriculture for British Guiana (Demarara) 1933, by Squire. An egg parasite, *Hadronotus rugosithorax* Ashm., is reported to affect up to 95 per cent of the eggs. A fly which acts as a typical "fruit fly" is also serious. The insect is *Melanoloma* sp. nov. (det. Green). On a wild pineapple variety known as "siengrassie," a species of mealybug, not *Pseudococcus brevipes*, was found which produced discrete chlorotic spots. It is oviparous.

MEALYBUGS IN CACAO.—In view of the recent findings by Posnette *et al.* that mealybugs are transmitters of a virus disease of cacau, it was thought useful to test the effect of mealybugs on cacau plants in an area where the virus disease was unknown. Accordingly, young cacau plants, growing in small cans in the Rio Botanic Gardens were infested with mealybugs in the following manner: Single mealybugs were attached to the edges of the latest matured leaves by caging them in a small felt and celluloid cage just below the growing point and before the new "flush" of leaves emerged. In other cases, a gross colony of mealybugs was caged over the top set of mature leaves and the growing tip, the mealybugs being allowed to settle at will.

Pseudococcus longispinus from ferns, *P. maritimus* from *Solanum tuberosum* and *P. citri* from jack fruit, *Artocarpus integrifolia*, were used in this manner. Only from infestations with *P. citri* were any significant indications obtained. In these cases, the gross colony killed the growing point and adventitious budding followed. The single leaf infestations resulted first in an abnormal "witches broom" effect of the bud and when the new leaves emerged to a length of a few centimeters, they became brittle and could be flicked off with the finger.

Dr. Verlande Duarte Silveira advised that later developments were as follows: "The cacao trees we inoculated in my laboratory all died of the disease, not having reached the stage of producing normal leaves and it appears that this was due to the intoxication produced by *Pseudococcus*. This was also true of the plants which were in the Jardim Botanico."

Since *Pseudococcus citri* was found on other cacau plants in the Rio Botanic Garden but with no symptoms evident, the experiment indicated that *P. citri* from the jack fruit had injected specific oral secretions. The initial effect was clearly one of inducing leaf abcission.

Xyleborus affinis EICHOFF ON MANGO.—Mango trees in the vicinity of Recife in the state of Pernambuco were reported dying in large numbers. Trunk samples seen by the writer showed exit holes of borers but infestations seemed inadequate to account for the reported rapid death of the trees. An affected area was visited where freshly felled trees had been cut into sections. These revealed wedge-shaped stained areas in cross section, suggestive of Dutch elm disease or blue stain fungus and with Dr. A. Chavres Batista, the tentative diagnosis was made that the mango trees were dying of a disease similar to those named and probably transmitted by the borer. Dr. Batista addressed himself to this problem with great earnestness and has since published a detailed account of the relationship between the borer *X. affinis* and the pathogen *Diplodia recifensis* Batista which completely confirmed the field diagnosis (Batista 1947).

The Sauva ant (Attus. sp.): This ant is a scourge in tropical South America. It will completely devastate growing crops in the vicinity of its nest and effective control measures would be of enormous importance. The writer had opportunity to test the effectiveness of D-D mixture as a fumigant. A single nest approximately 65 sq. yds. in extent and from 4 to 6 feet high lay squarely in the middle of the field plot area of the Institute for Agronomy Research. Holes were drilled a yard apart over the whole nest area and from 1 to 3 feet deep. 50 cc. of D-D mixture was poured into each hole to a total

of 3250 cc. Activity of the nest ceased. Dr. Batista reported later that one small center of activity was noted which was eliminated with an additional treatment of 500 cc. It is altogether likely that soil fumigation will provide an economic answer to one of the most serious agricultural problems in the whole of tropical South America.

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Aphid Control Experiment on Potatoes in California—with Special Reference to the Selective Action of DDT Dusts

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Field plots to test some of the organic insecticides in connection with aphid infestations of potatoes were initiated in California during the Spring of 1948, and the salient features of the results have been reported previously (Sylvester & McLean 1949). From the preliminary work, two insecticidal dusts, of the four tested, indicated promise for commercial use, *viz.*, DDT and parathion, and consequently formulations of these two dusts were tested during the Spring of 1949.

During the 1948 season, the DDT dust used (DDT 5 per cent; sulfur 50 per cent), while giving good control in final analysis, had two disadvantages which might mitigate against its usefulness in the control of aphids on potatoes. One was the relative slowness in action, requiring approximately two weeks before the toxic effects were notable on fairly high populations of the green peach aphid, *Myzus persicae* (Sulzer), and the other was a tendency for the potato aphid, *Macrosiphum solanifolii* (Ashmead),[1] to continue to increase in numbers in spite of weekly dustings.

However, the number of individuals of the potato aphid taken in the samples during the 1948 season were too small to be of any significance, but the tendency for it to resist the toxic action of the DDT-sulfur dust was strong enough to indicate a trend that justified further work.

The parathion dust, containing 0.5 per cent parathion, gave good aphid control, without any indications of selective action as far as species was concerned.

The failure of DDT to control the potato aphid to the extent which it will control the green peach aphid has been noted before (Gyrisko, Wene, and Rawlins 1946), and the reason suggested for this was lack of sufficient deposit of toxic material on the rapidly growing foliage, especially on the tops of the plants where the potato aphid is often found, particularly during the later phases of population development.

MATERIALS AND METHODS.—In order further to test DDT and parathion for the control of aphids on potatoes, a series of randomized replicated plots was again established in Kern County. Two locations were utilized, one in the Arvin district, and the other in the Shafter district. This placement of the plots made it possible to sample aphid populations in the two most important potato-growing areas of Kern County. Four replications of 4 treatments and an untreated check were used in each location. The individual plots were made up of 6 rows of field planted potatoes, and were 60 feet long. The dusts were applied in the early morning, with a

[1] The identification of the potato aphid, *Macrosiphum solanifolii* (Ashmead), was made by E. O. Essig.

rotary type hand duster, and a total of 3 applications, one week apart, were made. The following dusts were employed in the treatments: (1) DDT 5 per cent, sulfur 50 per cent, inert carrier 45 per cent; (2) DDT 5 per cent, heavy oil 2 per cent, inert carrier 93 per cent; (3) parathion 1 per cent, inert carrier 99 per cent; and (4) parathion 2 per cent, inert carrier 98 per cent. The mean rate of application was as follows: DDT-sulfur, 33 pounds per acre; DDT-oil, 40 pounds per acre; 1 per cent parathion, 28 pounds per acre; 2 per cent parathion, 30 pounds per acre.

For sampling purposes, the 4 middle rows of each plot were used, the two outside rows serving as buffer rows. Five top leaves and 5 bottom leaves, selected at random from the 4 count rows, comprised the individual sample. Examination of both surfaces of the individual leaves was made, and the aphids were recorded as to species, *i.e.*, the green peach aphid, the potato aphid, and miscellaneous transient species. In addition, the individuals of each species were grouped as to the stage, *i.e.*, alate, aptera, or nymph. As long as the plots were being dusted, both pre-treatment (24 hours prior to treatment) and post-treatment (24 hours following application) counts were made. The pre-treatment samples were continued on the established schedule for 3 weeks following discontinuation of the dusting. For purposes of analysis, only the pre-treatment samples were employed.

RESULTS.—Table 1 gives the results of the various treatments on the total seasonal population. All treatments were of value in controlling the aphids. The DDT-sulfur dust gave the least degree of control of the population, but the indications were that the incorporation of a small percentage of heavy oil in a 5 per cent DDT dust had considerable value in increasing its toxicity.

Table 1.—Results of aphid control treatments indicating the influence of the various treatments upon the aphid populations.

TREATMENT	MEAN NUMBER OF APHIDS PER 10 LEAF SAMPLE
DDT 5 per cent; sulfur 50 per cent; inert carrier 45 per cent	3.10
DDT 5 per cent; heavy oil 2 per cent; inert carrier 93 per cent	1.48
Parathion 1 per cent; inert carrier 99 per cent	0.39
Parathion 2 per cent; inert carrier 98 per cent	0.13
Check, untreated	8.68
Diff. req. for signif.	
5 per cent	1.51
1 per cent	2.03

Table 2.—Results of aphid control treatments indicating the influence of the various treatments upon the two species of aphids infesting potatoes, i.e., *Myzus persicae* and *Macrosiphum solanifolii*.

TREATMENT	MEAN NUMBER OF APHIDS PER 10 LEAF SAMPLE	
	Myzus persicae	*Macrosiphum solanifolii*
DDT 5 per cent; sulfur 50 per cent; inert carrier 45 per cent	0.37	5.83
DDT 5 per cent; heavy oil 2 per cent; inert carrier 93 per cent	0.47	2.50
Parathion 1 per cent; inert carrier 99 per cent	0.33	0.45
Parathion 2 per cent; inert carrier 98 per cent	0.23	0.05
Check, untreated	13.41	3.95
Diff. req. for signif.		
5 per cent	2.16	
1 per cent	2.85	

In table 2, the insecticidal action of the 4 treatments can be seen as it operated upon the two species of aphids which made up the majority (some 99 per cent) of the total individuals counted. All of the insecticides gave excellent control of the green peach aphid, without any difference being noted between them. However, in connection with control of the potato aphid, the inefficiency of the DDT dusts, particularly the DDT-sulfur dust, can be noted. Neither of the DDT dusts used was able to control this species, but statistically the use of a DDT-oil dust had a distinct advantage over the DDT-sulfur dust. Both of the parathion dusts used were effective in reducing the numbers of the potato aphid; however, only the 2 per cent concentration exhibited any particular advantage over the DDT-oil dust, and this was slight (significance at the 5 per cent level).

A more complete summation of the data obtained is found in table 3. Here the results of the treatments upon the

weekly populations of the two species can be followed. Control of the green peach aphid, by all of the insecticides, is indicated during the entire course of the population development. The potato aphid, however, continued in almost a normal course of development upon the DDT-sulfur plots, but during the sixth week when this species was declining in numbers on the check plots, the population on the DDT-sulfur plots was continuing to increase. In fact, there appears to be a stimulating effect occurring upon these plots. The DDT-oil dustings apparently were able to more effectively check the development of the potato aphid for a period of 5 weeks, but between the fifth and sixth week sampling periods, again a great increase in the population occurred, an increase of a magnitude that apparently was foreign to the normal untreated population.

Table 3.—Results of aphid control experiments on potatoes indicating the influence of the various treatments upon weekly populations of *Myzus persicae* (Sulzer) and *Macrosiphum solanifolii* (Ashmead).

Treatment	Species	Mean Number of Aphids per 10 Leaf Sample					
		Week					
		1st(1)[1]	2nd(2)	3rd(3)	4th	5th	6th
DDT 5 per cent; sulfur 50 per cent; inert carrier 45 per cent	*M. persicae*	0.00	0.25	1.25	0.00	0.37	0.37
	M. solanifolii	0.25	0.00	2.50	4.50	6.00	21.75
DDT 5 per cent; heavy oil 2 per cent; inert carrier 93 per cent	*M. persicae*	0.25	1.75	0.12	0.12	0.00	0.62
	M. solanifolii	0.12	0.00	0.00	0.37	0.87	13.62
Parathion 1 per cent; inert carrier 99 per cent	*M. persicae*	0.00	0.87	0.12	0.00	0.00	1.00
	M. solanifolii	0.00	0.00	0.00	0.00	0.00	2.75
Parathion 2 per cent; inert carrier 98 per cent	*M. persicae*	0.75	0.12	0.00	0.12	0.00	0.37
	M. solanifolii	0.00	0.00	0.00	0.00	0.00	0.25
Check, untreated	*M. persicae*	0.12	1.00	4.37	18.00	29.00	28.00
	M. solanifolii	0.00	0.37	1.00	3.00	10.62	8.75
Diff. req. for signifi.							
5 per cent		5.30					
1 per cent		6.98					

[1] The numbers in the parentheses indicate when the various weekly treatments were applied in respect to the pre-treatment counts.

DISCUSSION.—The seasonal population of aphids encountered at the two locations, during the six weeks which samples were taken, was primarily composed of two species of aphids, *viz.*, the green peach aphid, and the potato aphid. On a percentage basis, the former species made up approximately 53 per cent of the total, while the latter species made up approximately 47 per cent of the total numbers involved. Based upon the two levels of sampling, *i.e.*, the top and bottom leaves, 92 per cent of the green peach aphids counted were taken on the bottom leaf samples (leaves in contact with the ground) with some 8 per cent being taken on the top leaf samples. In the case of the potato aphid, approximately 83 per cent of the individuals encountered were on the bottom leaves, with about 17 per cent being taken on the top leaves. In both locations, the potato aphids were initially found on the bottom leaves, and were encountered on the top leaves approximately two weeks after first being noted on the bottom leaves, except for two alate specimens and one nymph.

These observations would seem to indicate that the development of a potato aphid population would follow a pattern similar to that of a green peach aphid population, *viz.*, the initial phases of infiltration would be alate, with these forms locating on the bottom leaves of the potato plant, in which place they would begin to produce their young. After a period of time, the population would enter a more active phase, and begin to disperse and move upwards on the potato foliage. The factors which would contribute towards this dispersal are unknown.

The important thing, as far as these particular control plots are concerned, is the initiating phase during which the

potato aphid is present along with the green peach aphid on the lower leaves of the plants. During this phase the insecticide dusts were in sufficient toxic concentrations to prevent further build-up of both species, in the case of parathion, and the green peach aphid, in the case of the DDT dusted plots. Consequently, it would appear as if the DDT-sulfur dust exhibited a selective toxic action, being effective to a high degree against the green peach aphid, but not against the potato aphid. The addition of oil to a 5 per cent DDT dust apparently decreased this selective action, but during the final sampling period the potato aphid, even in this case, was able to overcome the initial handicap and rapidly increase in numbers.

If the untreated check plot records can be used as the standard of the normal course of population development, the peak, as far as number of insects is concerned, occurred during the fifth week, and was passed by the time the sixth sample was taken. However, the potato aphid population on both the DDT-sulfur and DDT-oil plots, between the fifth and sixth weeks, increased to a higher point than was obtained on the untreated plots, and the degree of increase was of a magnitude that was not normally encountered in any previous week of sampling. Consequently, there would appear to be an actual stimulating effect due to the DDT, but beyond this little can be said, and the exact mechanism of action remained obscure. However, it can be noted that field observations of the coccinellid and chrysopid predator activities, did not indicate any difference due to the treatments.

SUMMARY.—The results obtained from small replicated field plots, established for the control of aphids on potatoes, using the following insecticidal dusts: (1) DDT 5 per cent, sulfur 50 per cent; (2) DDT 5 per cent, heavy oil 2 per cent; (3) parathion 1 per cent; and (4) parathion 2 per cent; indicate that all will give control of the aphids.

However, the control is primarily due to the high efficiency of the insecticides upon populations of the green peach aphid *Myzus persicae* (Sulzer), and if considered from the standpoint of controlling the potato aphid, *Macrosiphum solanifolii* (Ashmead), the dusts containing parathion and that containing DDT and oil are the only materials that will give control DDT-sulfur dust will not control the potato aphid, in fact the indications are that during later phases of population development, it may exhibit a stimulating effect. This stimulation effect also was exhibited by the DDT-oil dust, but occurred at a later time in relation to discontinuation of application The factors involved in this selective action of DDT on the two species are not known, nor are those involved in producing an increase in numbers of the potato aphid. In view of this, the use of DDT-sulfur dusts cannot be advocated under conditions where the potato aphid is a species to be considered, and is potentially the species which will contribute the bulk of the aphid population. The incorporation of oil in a DDT dust offers greater possibilities for control of both species, but still may, under certain conditions, allow a build-up of the potato aphid.

Parathion, either in concentrations of 1 or 2 per cent, will control both species of aphids encountered, and apparently with equal efficiency.

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DR. NEWELL GOES TO HAWAII

Dr. Irwin M. Newell, formerly on the teaching staff at the University of Oregon, is now associate entomologist at the Hawaii Agricultural Experiment Station, Honolulu. Doctor Newell expects to spend six months in India during 1949, looking for parasites of the oriental fruit fly, *Dacus dorsalis*.

Insect Vectors of Cantaloupe Mosaic in California's Desert Valleys[1,2]

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In recent years a virus disease called cantaloupe mosaic has become a limiting factor in the production of early-summer melons in the desert valleys of southern California and Arizona, but particularly in the Imperial Valley of California. Losses from this disease during the 1947 and 1948 seasons amounted to about one-third of the crop.

Melons (cantaloupes, honeyballs, honeydews, and Persians) are grown in these areas from seed planted from December to March, so that the crop ripens in May and June. The earlier plantings are made under hotcaps for protection from frosts and wind. Plantings are made in hills 27 inches apart, on the south side of beds 7 feet wide and of variable length, laid out east and west. After the plants emerge, each hotcap is lifted, the plants are thinned to two per hill and weeded, and the hotcap is replaced with the east side left open. The hotcaps are removed when the plants push against them, ordinarily about the first of April.

The Disease.—The viruses most commonly found in melons in this area are all members of the cucumber virus series. A survey was conducted in the Imperial and Palo Verde valleys to determine the frequency of the several viruses present. One hundred and seventy-nine collections were made from 53 diverse stations. Of this total, 6 were found to be cucumber virus 1; 13 were a cucumber virus; and 160 were squash-mosaic virus. Apparently the most common and damaging virus is the squash-mosaic virus originally described by Freitag (1941a).

The symptoms of these three virus diseases have been previously described by Middleton & Whitaker (1946). They are similar and difficult to distinguish in melons. The viruses cause a conspicuous mosaic pattern in the leaves, with some rolling and disfiguration, and usually reduce the size of the leaves without material alteration of their perimeter. The petioles and stems may be slightly mottled. Immature fruits are conspicuously mottled, with more or less circular, raised, dark-green areas upon a light-green background; fruits are frequently distorted into odd shapes. The net on ripening cantaloupe fruits on infected plants fails to develop properly in aerial extent and depth, and as a consequence the sutures appear broad and shallow. Normal-appearing cantaloupes from mosaic-infected vines are lower in total soluble solids than fruits from healthy vines.

Cucumber virus 1 has a wide host range that includes a large number of species in several plant families. Squash mosaic is practically limited to cucurbits in its host range. The virus called a cucumber virus in this paper has a host range very similar to that of squash mosaic, except that it does not infect watermelon.

The Vectors.—Freitag (1941b) reported that the squash-mosaic virus is transmitted both by aphids and by cucumber beetles, but only very inefficiently by aphids. Later work by Freitag (in press) has shown that aphids are inefficient in transmitting this virus only when fed for a long period on diseased plants, but are quite efficient when starved and then fed for 1 minute or less on the diseased plant. These findings are confirmed by the data in table 1.

The virus strain used in the present studies came from the Imperial Valley. As is shown below, the aphid vectors in this area commonly feed for only short periods on each plant. Cucumber beetles are rare in the desert valleys during the time that the virus is being spread.

Nine sticky-board trap assemblies using the yellow sticky boards developed by Kaloostian & Yeomans (1944) were set up to sample the aphid flights in the Imperial Valley during the 1948 and 1949 seasons. Each of these assemblies consisted of a post with four cross-arms on it, so arranged that four yellow sticky boards 5″×10″ could be fastened to them top and bottom, in a vertical position. The tops of the sticky boards were about

[1] Pacific Slope Branch Program, 1949.
[2] Paper No. 606, University of California Citrus Experiment Station, Riverside, California.
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[4] R. A. Flock and M. McD. Johnson also participated in the studies herein reported.

Table 1.—Results of tests to determine the efficiency of single aphids of various species in the transmission of squash-mosaic virus after long and short feeding periods on diseased plants.

Aphid Species	Feeding Period					
	Long			Short		
	Total Number of Plants	Plants Infected		Total Number of Plants	Plants Infected	
		Number	Per Cent		Number	Per Cent
Myzus persicae (Sulz.)	20	3	15	50	39	78
Aphis medicaginis Koch				10	6	60
Aphis maidis Fitch				20	1	5
Macrosiphum solanifolii (Ashm.)				10	4	40
Macrosiphum pisi (Kalt.)				10	2	20

4.5 feet from the ground, and on each post two faced east and west and two faced north and south.

Aphid catches for the 1948 and 1949 seasons in the Imperial Valley are shown in figure 1, together with the percentage of melon plants showing mosaic symptoms. There is a striking difference between the two seasons, both in aphid population and in mosaic infection. Melon plants were injured much less during the 1949 season than in the two previous years, both because of the lower percentage of mosaic infection and because, in most fields, the mosaic appeared too late to cause much crop loss. If a melon plant is not infected until after the crop is set and nearly matured, little or no injury results. In 1949 severe crop injury was confined to a few late fields.

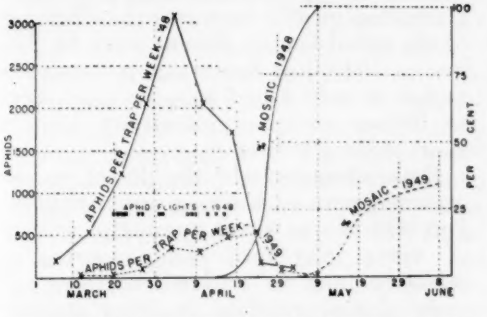

FIG. 1.—Aphid catches on sticky-board traps, in relation to the appearance of mosaic symptoms in melon plants in the Imperial Valley in 1948 and 1949. Dates of heavy aphid flights during 1948 are shown.

Aphid populations in the Palo Verde Valley were lower during the two seasons studied than the corresponding populations in the Imperial Valley. There was also less mosaic in the Palo Verde Valley both seasons. During the 1949 season, aphids were particularly scarce in the Palo Verde Valley, with the result that cantaloupe mosaic was difficult to find, except in two or three fields. The lower populations of aphids in the Palo Verde Valley seem to be tied in with the absence of sugar beets, which are not grown there because of the presence of Texas root rot fungus in the soil.

Table 2.—Aphid species most commonly caught on sticky-board traps in the Imperial Valley, 1948 and 1949.[1]

Aphid Species	1948		1949	
	Number	Per Cent	Number	Per Cent
Myzus persicae (Sulz.)	79,038	80.8	9,294	52.5
Brevicoryne brassicae (L.)	7,836	8.0	1,946	11.0
Rhopalosiphum pseudobrassicae (Davis)	2,606	2.7	701	4.0
Macrosiphum pisi (Kalt.)	2,052	2.1	1,808	10.2
Hyalopterus arundinis (Fabr.)	1,345	1.4	1,756	9.9
Aphis maidis Fitch	1,189	1.2	273	1.5
Toxoptera graminum (Rond.)	964	1.0	283	1.6
Aphis gossypii Glover	21	0.02	3	0.02
About 28 other species	2,783	2.8	1,636	9.2
Totals	97,814		17,700	

[1] The melon aphid, *Aphis gossypii*, is included in this table to show its rarity.

The more numerous aphid species caught on the traps are listed in table 2. The green peach aphid, *Myzus persicae* (Sulz.), was the most numerous aphid both years. It seldom breeds on melons, but breeds in enormous numbers on sugar beet, lettuce, and various weeds, particularly *Chenopodium* spp. and *Malva* sp. It may be noted here that the increase in aphid populations and mosaic prevalence in the Imperial Valley occurred at the time that sugar beets became an important crop in that area. The cabbage aphid, *Brevicoryne brassicae* (L.), breeds on cabbage and wild mustard, while the turnip aphid, *Rhopalosiphum pseudobrassicae*

(Davis), breeds chiefly on wild mustard. The pea aphid, *Macrosiphum pisi* (Kalt.), breeds on various legumes, but chiefly on alfalfa. The mealy plum aphid, *Hyalopterus arundinis* (F.), breeds exclusively on *Phragmites* in this area. The corn leaf aphid, *Aphis maidis* Fitch, and the greenbug, *Toxoptera graminum* (Rond.), breed on various grasses, but most of them come from barley. Several of these species are listed in table 1 as vectors of squash mosaic. The melon aphid, *Aphis gossypii* Glover, was rare both years, and was not a factor in the mosaic transmission.

During the 1949 season, the traps, which were in approximately the same locations they had occupied in 1948, caught only 18.1 per cent as many aphids as they had caught the previous year. It is probable that there was actually more difference than that between the years, since at the height of the 1948 flight season many of the traps became so full of aphids that they could not catch all those flying into them.

VECTOR BEHAVIOR.—Attempts to measure the actual density of the aphid flights were not altogether successful. The sticky-board traps attract aphids, and for this reason the aphids caught on such a trap cannot be assumed to have been traveling only through an area the size of the board. According to other methods, an estimated forty million aphids passed a 1-mile front each hour during a heavy flight. These heavy flights occurred only during calm periods of relatively high temperature. They did not ordinarily last more than 3 or 4 hours, and occurred on less than half the days during the population peak. Aphids do not fly during high winds, and as a result a high population of newly-emerged alates is built up on the source plants in the course of the windy periods, which ordinarily last about 3 days in this area. As soon as the wind dies down and the temperature rises, the winged aphids take off in swarms. Flight is apparently at random, so that the aphids move with the air drift, gradually spreading out as they go. Although it was impossible to follow individual aphids, or even swarms, through their entire flight, some evidence was accumulated to indicate that these aphid swarms did not move much more than 5 miles. Scattered individuals covered a somewhat longer distance.

Observations were made on the feeding behavior of alate aphids on melon plants, especially during the 1948 season. It was first observed that there never was a high concentration of aphids on the plants even though very heavy flights were passing over the fields. Counts made during heavy flights showed that the number of aphids landing on each melon hill averaged about 50 per minute, and that the number leaving during this period was about the same. It was also observed that each aphid began feeding immediately after it landed, and that the feeding period, or periods, per aphid totaled 40 seconds on the average. Having fed for this short period, the aphid withdrew its beak, walked up to the tip of a leaf, and flew away. It was seldom possible to follow an individual aphid in flight, but some aphids were seen to alight on nearby plants, or even on the same plant, and to repeat the short feeding period. It was obvious that each aphid was moving across the fields in a succession of short flights, feeding for short periods on a large number of plants.

The work of Watson (1936) and of Watson & Roberts (1939) has shown that with a nonpersistent virus of this type a short feeding period following a period of starvation greatly increases the efficiency of the aphid vector. Recent work by Sylvester (1949) has shown that a starvation period of only 2 to 5 minutes may serve to induce increased infectivity from a short feeding period.

EPIDEMIOLOGY.—In the desert melon-growing areas, each season apparently begins with a very small number of sources of virus infection. These sources of infection may be native *Cucurbita palmata* plants, zucchini or other summer squash plants which are grown through the winter in the Imperial Valley, volunteer melons, or seed-borne infection of melon and squash plants, as reported by Middleton (1944).

Virus infection is so rare early in the season that it is difficult to find. We were able to find only one case of seed-borne mosaic in the desert areas in 1949, even though a considerable number of plants were scouted. This may be a result of the virus-free seed program. The overwhelming numbers of potential aphid vectors that move over the fields in certain years,

pick up this rare and scattered virus inoculum and increase it in an almost geometrical ratio. Presumably, few of the first aphids to invade the fields become infective owing to the rarity of the primary sources of inoculum. Those aphids that become viruliferous infect a number of plants as soon as the hotcaps are removed. These infected plants also soon become sources of virus inoculum, so that the number of infective aphids is increased; these then infect more plants, and so on. This explains the almost explosive increase in prevalence of the mosaic infection observed in certain years, as shown in figure 1.

None of the aphids caught flying early in the season in the Imperial Valley infected melon plants when confined to them, but two infective aphids were caught late in the 1948 season. The number of aphids that could be tested in this way was an almost infinitesimal fraction of those flying in the area. Work done in a screenhouse in the Imperial Valley has shown that after infection, melon plants become a source of virus inoculum in about half the time required for the appearance of symptoms. It should be noted that the presence of volunteer melon plants in fields in which melons had been grown the previous year may nullify the use of virus-free seed.

INSECTICIDES AND REPELLENTS.—Attempts were made to control the spread of cantaloupe mosaic by the use of insecticides and repellents. The insecticides used were applied as dusts by airplane equipment, namely: 5 per cent DDT at 30 pounds per acre; 1 per cent DDT and 2 per cent oil at 40 pounds; 1 per cent parathion at 30 pounds; 1 per cent gamma isomer of benzene hexachloride at 20 pounds; 4 per cent nicotine at 30 pounds. These materials were applied three times to 10-acre blocks on three farms, at intervals of about one week during the height of the aphid flights. Aphids seemed to be able to fly through the insecticide cloud without ill effect. No measureable degree of mosaic control was obtained by any of the treatments. Aphids did not become established on either treated or untreated cantaloupes.

It was reasoned that, since the mosaic was being transmitted by a transient vector population, the most effective control should be obtained either by reducing the aphid population on the breeding hosts (in this case sugar beets) or by using an effective aphid repellent on the melon plants. Because of the large acreage of breeding hosts involved, it was not possible to test the former method of vector control. Attempts were therefore made to find an aphid repellent. A number of plant oils, known repellents for other insects, and various evil-smelling substances were made into dusts and applied on young melon plants at weekly intervals. The only one of these to show a measurable degree of control was tetramethyl thiuramdisulfide, particularly when used at 10 per cent, and the use of this compound resulted in a delay of only a few days in the appearance of mosaic.

The hope that a repellent could be found was based on the observation that, on approaching a plant, in normal flight, an aphid hesitates for a fraction of a second at a distance of 1 to 1.5 inches from the plant surface. At this point the aphid appears to be sensing, perhaps smelling, the plant to decide whether or not to land. If the plant could be made unattractive to the aphid, it would fly on without landing, and its potential as a vector would be nullified.

SUMMARY.—A virus disease called cantaloupe mosaic has caused severe injury to early-summer melons in the Imperial Valley of California in recent years. At least three viruses were found to be causal agents of this disease, but the greater part of it was caused by the squash-mosaic virus.

Spread of the disease was by transient populations of aphids, chiefly the green peach aphid. These aphids did not breed on the melon plants but came from sugar-beet fields and weeds, and moved across the melon fields in swarms. Each aphid fed only about 40 seconds on each melon plant. It moved across the field in a succession of short flights, feeding on a considerable number of melon plants in succession. This type of feeding is so very efficient in spreading the virus that an extremely low initial incidence of virus infection was increased very rapidly. A low aphid population in 1949 was reflected in a low percentage of mosaic infection.

No effective control was obtained by the use of insecticides or repellents.

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Off-Flavors in Peaches Sprayed with Benzene Hexachloride[1]

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The use of benzene hexachloride for the control of plum curculio, *Conotrachelus nenuphar* (Hbst.), on peaches has looked very promising. While previous work done elsewhere indicated, in general, that no off-flavor would result if the benzene hexachloride were applied early enough in the season, there have been some suggestions to the contrary. Bobb (1946) indicated that when used in sprays for the control of the second brood of plum curculio, benzene hexachloride imparted a musty, disagreeable taste to the fruit which lasted as long as 4 weeks after application. Snapp (1947) pointed out that benzene hexachloride may adversely affect the flavor of peaches if applied too close to harvest. Davis (1948) reported that off-flavor in canned peaches was detected in all samples of canned peaches sprayed with two applications of benzene hexachloride and that there seemed to be little relationship between the last spray-to-harvest interval and the degree of off-flavor. Snapp (1948) found no adverse affect on the fruit following four applications of benzene hexachloride, all more than 4 weeks before harvest. Reports of the production of undesirable flavors in other crops, notably in potatoes in the Connecticut Valley in 1947, suggested that the possible development of an off-flavor in peaches grown in this area should be investigated.

In the summer of 1948 an 8 year old variety peach orchard at the University of Massachusetts was sprayed on May 29, June 3, and June 10 with a commercial benzene hexachloride preparation containing 6 per cent gamma isomer and 40 per cent other isomers and formulated as a 50 per cent wettable powder, at the rate of 2 pounds per 100 gallons. Two pounds of a 50 per cent wettable DDT and 6 pounds of a wettable sulfur were included also. As a check, one tree each of the early varieties, Greensboro, Mikado, Marigold and Oriole, were sprayed with a mixture containing no benzene hexachloride. It was thought that any off-flavor would be most likely to occur in the first varieties to ripen. As each variety was picked samples of tree-ripened fruit from the sprayed and unsprayed trees were taken to the Department of Food Technology for canning, freezing and tasting as fresh fruit. As part of another project samples of fruit of 32 other varieties, all of which had been sprayed with benzene hexachloride, in the same schedule, were canned and frozen.

PROCESSING METHODS.—*Canning:* The peaches were washed and blanched for 60 seconds in boiling water. After being cooled in cold water they were peeled, sliced and packed into pint home canning jars. The jars were then filled with boiling 40 per cent sugar syrup, sealed, and

[1] Contribution No. 698, Massachusetts Agricultural Experiment Station.

processed for 25 minutes in a boiling water bath.

Freezing: Sliced peaches, as prepared for canning, were mixed with sugar in the ratio of four parts of peaches to one part of sugar. They were then packed in pint home canning jars, sealed, and frozen and stored at −10° F.

RESULTS.—In tests on the fresh peaches at the time of harvest no definite off-flavors, which could be attributed to benzene hexachloride, were detected.

The canned and frozen peaches were tested for off-flavors approximately two months after they had been packed. The samples were checked by a taste panel consisting of 12 members. It should be noted that several of the panel members had participated in peach-variety-quality tests during several years as part of a separate project. The results of the individual tasters were quite uniform so far as the detection of off-flavors in the processed peaches was concerned.

In tests with canned products from the four early varieties of peaches sprayed with benzene hexachloride: Oriole had a slight off-flavor; both Mikado and Marigold showed a strong off-flavor, and in Greensboro it was very strong. None of the control fruit which had not been sprayed with benzene hexachloride showed any off-flavor.

The other 32 varieties of peaches which were canned had varying degrees of off-flavors ranging all the way from none to very strong. As in the tests reported by Davis (1948) there was no apparent relationship between the intensity of the undesirable flavors due to benzene hexachloride and the elapsed time between the last spray and picking. These intervals and the results of all the tests on canned peaches are shown in table 1.

Table 1.—Off-flavor in canned peaches from benzene hexachloride spray.

VARIETY	DAYS FROM LAST SPRAY TO PICKING	VARIETY	DAYS FROM LAST SPRAY TO PICKING
No Off-flavor		Primrose	102
Golden Jubilee	74	Kalhaven	102
Triogem	81	Sungold	102
Early Halehaven	81	White Hale (white)	103
Pacemaker	90	J. H. Hale	104
Slight Off-flavor		Elberta	105
Oriole	71	Shippers Late Red	107
Red Haven	71	Afterglow	111
Raritan Rose (white)	74	Strong Off-flavor	
Culbertson Champion (white)	76	Mikado	65
New Jersey 116	81	Marigold	65
Vedette	84	Sunhigh	81
Valiant	84	Golden Globe	84
Red Rose (white)	85	Goldeneast	84
Colora	85	Ideal	90
Halehaven	85	Early Elberta	103
Ambergem	90	Belle of Georgia (white)	103
Michigold	90	Very Strong Off-flavor	
Summercrest	90	Greensboro (white)	65
Veteran	90	Eclipse	85

Table 2.—Development of off-flavors in canned peaches reprocessed from frozen products which had no detectable off-flavor from benzene hexachloride applications.

VARIETY	DAYS FROM LAST SPRAY TO HARVEST
No Off-flavor	
Golden Jubilee	74
Halehaven	85
Vedette	84
Oriole	71
Slight Off-flavor	
Mikado	65
Eclipse	85
Afterglow	111
Goldeneast	84
Greensboro (white)	65

Of the 36 varieties which were sprayed with benzene hexachloride, 4 (11.1 per cent) had no off-flavor, 22 (61.1 per cent) showed a slight off-flavor, 8 (22.2 per cent) had a strong off-flavor, and 2 (5.5 per cent) were recorded as having a very strong off-flavor. Those samples with a very strong, or strong off-flavor were considered inedible by all tasters, and many of those evaluated as having a slight off-flavor would be considered inedible by some people.

The above results indicate that the absence of an off-flavor in fresh raw peaches sprayed with benzene hexachloride is no indication that the canned product will be satisfactory. Heating the peaches as done here appears to bring out or develop the off-flavor. It would likewise appear that if such fresh peaches were used in cooked dishes, an off-flavor, similar to that of the canned product might develop, although this point has not been checked.

In similar tests on the above varieties which had been frozen no evidence of off-flavors which could be attributed to the benzene hexachloride spray could be detected when the samples were allowed to thaw and come to room temperature for normal tasting. These results provide further evidence that heating may be necessary to bring out the off-flavor in

peaches sprayed with benzene hexachloride.

In order to obtain a further check on the effect of heating or processing on the off-flavor in peaches samples of nine varieties of the frozen peaches were thawed and were then canned by packing them in home canning jars and processing for 25 minutes in boiling water. The results of the taste tests on the frozen and recanned peaches are shown in table 2.

It may be seen that in some cases frozen peaches, all of which showed no off-flavor when thawed, tended to develop an off-flavor (of the benzene hexachloride type) after being canned. These tests provide further evidence that heating appears to be necessary to bring out the off-flavor that may be encountered in peaches which have been sprayed with benzene hexachloride.

DISCUSSION AND CONCLUSIONS.—These results show that peaches sprayed with benzene hexachloride to control plum curculio under Massachusetts conditions may develop an off-flavor when subjected to heating in the canning process. While in many varieties the flavor was unaffected or so slightly off as to go unnoticed by a majority of people, it was strong enough in a few to make the canned product undesirable and in at least two varieties so strong that they were practically inedible. It was observed also that those varieties which did not have a definite off-flavor were lacking in the normal peach aroma and flavor (and tasted slightly more acid).

Among the varieties which were canned or frozen and then reprocessed by canning there were varietal differences in amount of off-flavor but these differences were not correlated with flesh color or season of ripening.

It was also observed that in the peaches which did not exhibit a definite off-flavor there was a lack of the normal peach aroma and flavor. Similar observations were made on the fresh peaches at the time of harvesting. While no definite off-flavor could be detected, the fruit was considered to be lacking in its characteristic peach flavor and somewhat "flat" or insipid in flavor. This is not attributable definitely to the benzene hexachloride spray since uncontrolled environmental factors contribute to the quality of the fresh peach fruit.

SUMMARY.—A 50 per cent wettable powder of benzene hexachloride containing 6 per cent gamma isomer at 2 pounds per 100 gallons was applied in each of three sprays to 36 varieties of peaches to control plum curculio. Tree-ripened fruits were canned, frozen and tasted as fresh fruit. No off-flavor attributable to benzene hexachloride was detected in the frozen or fresh products. When canned only four varieties showed no off-flavors. Detectable off-flavors in the other 32 varieties ranged from slight to strong and very strong. No correlation was observed between flesh-color or season of ripening and the intensity of the off-flavor.

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CHAS. J. SORENSON BECOMES EMERITUS RESEARCH PROFESSOR AT UTAH

Professor Charles J. Sorenson, who has been Research Professor of Entomology and Professor of Entomology in the Department of Zoology at this Institution, will become Emeritus Research Professor of Entomology and Emeritus Professor of Entomology, beginning July 1, 1949. Professor Sorenson has done outstanding work on the relation of Lygus bugs and mirids to alfalfa and alfalfa seed production, and on peach twig borer and other insects of importance in horticulture. Professor Sorenson will continue to teach the course in Agricultural Entomology and will continue his research.

Population Studies of the Long-Tailed Mealybug and Its Natural Enemies on Citrus Trees in Southern California, 1947[1]

PAUL DEBACH,[2] C. A. FLESCHNER,[3] and E. J. DIETRICK,[4] *Division of Biological Control, University of California Citrus Experiment Station, Riverside*

The long-tailed mealybug, *Pseudococcus longispinus* (Targioni), has in recent years become a pest of minor economic importance on citrus in southern California. Its occasional rise in population density and gradual spread to new areas, regardless of the establishment of a complement of species of introduced parasites, warranted the undertaking of a study to determine the factors affecting the long-tailed mealybug population in the field. Late in 1945 such a study was begun by the Division of Biological Control of the University of California. A detailed report of this project through the year 1946 (DeBach 1949) describes the appearance and spread of the long-tailed mealybug on citrus in southern California and gives a history of the introduction of parasites to combat this pest.

The purpose of the present paper is to report the data obtained in a continuation of the study of the factors affecting the long-tailed mealybug population in the same general area in the year 1947, and to analyze some of the differences in population trends in 1946 and 1947. Methods of obtaining the data in the more recent studies are described in detail in the account of the 1946 experiment (DeBach 1949). Briefly, corrugated cardboard bands placed around the trunks of trees and changed at monthly intervals were found to be highly adequate for simultaneously sampling populations of the long-tailed mealybug and its natural enemies.

A detailed monthly census, using the band method, was taken of the long-tailed mealybug and predator and parasite populations in selected orange groves in the Anaheim-Santa Ana area of Orange County during 1947. Experimental plots of 12 to 39 trees each were set up in nine groves. The trees within the plots were selected for initially uniform mealybug populations. To evaluate the effects of various factors, especially the effects of insecticidal residues on natural enemy populations, the trees were studied in groups of three as a unit. Three untreated trees, designated "check" trees, were studied intensively along with the others, and since they were found to represent quite accurately the population trends of the untreated portions of the grove as a whole, the data obtained from them are used in this presentation. Two of the experimental plots were lost during the year owing to insecticidal treatment by the owner for citrus pests other than the mealybug. Therefore, the data given were obtained from 21 trees, or from 3 trees from each of seven groves.

SPECIES OF PARASITES AND PREDATORS.—Six species of primary parasites, three species of secondary parasites, and eight species of predators were obtained from population samples of the long-tailed mealybug in this study, as follows:

Primary Parasites

Anarhopus sydneyensis Timb.
Chrysoplatycerus splendens (How.)
Coccophagus gurneyi Comp.
Pseudaphycus angelicus (How.)
Tetracnemus peregrinus Comp.
Tetracnemus pretiosus Timb.

Secondary Parasites

Lygocerus sp.
Procheiloneurus sp.
Thysanus niger (Ash.)

Predators

Chrysopa californica Coq.[5]
Cryptolaemus montrouzieri Muls.
Diplosis sp.
Hemerobius pacificus Banks
Lindorus lophanthae (Blaisdell)
Scymnus guttulatus Lec.
Scymnus sordidus Horn
Sympherobius californicus Banks

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[5] The designation *Chrysopa californica* Coq. apparently includes a complex of at least two species. It is used throughout this paper in the older, broader sense, as discussed by Clancy (1946).

Five species of primary parasites and two species of secondary parasites (listed below) were obtained from the monthly field collections of cocoons of the brown lacewing (*Sympherobius californicus* Banks) and of the green lacewing (*Chrysopa californica* Coq.), which were held in the laboratory for emergence to determine the percentage of parasitization of these predators.

Parasites reared from *Sympherobius Californicus* Banks:

Primary: *Aegilips* sp.

Secondary: *Dibrachys daphne* Girault

Parasites reared from *Chrysopa californica* Coq.:

Primary: *Chrysopoctonus patruelis* Cushm.
Hemiteles tenellus (Say)
Isodromus iceryae How.
Perilampus chrysopae Cwfd.

Secondary: *Dibrachys cavus* Walk.

CENSUS DATA.—The general relationship between the average populations per band (DeBach 1949) of mealybugs, predators, and parasites in the seven experimental orange groves during 1947 are graphically portrayed in figure 1. The total numbers of all species of parasites and hyperparasites are combined to depict the total measure of parasitization. To represent the numerical value of predators, the total numbers of all species of predators are combined and this total is multiplied by a factor of ten. The use of this ratio was explained by DeBach (1949): "Since one predator may kill, say 100 hosts, a different scale must be used for predator populations in order that they may approximate the same magnitude as host populations on the same graph. The ratio chosen does not necessarily represent the true numerical relation between the long-tailed mealybug and its predators in the field, nor is this necessary for analytical purposes. Despite the use of different scales for predators and host, their relative population changes in time remain the same, and this is what we wish to depict."

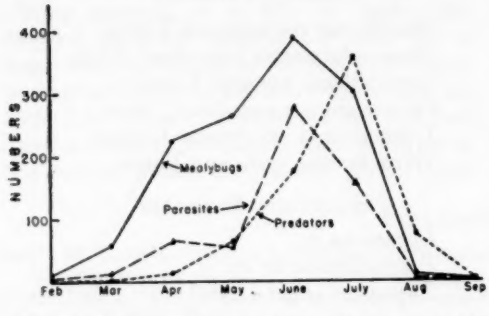

FIG. 1.—Relative changes in populations of the long-tailed mealybug, its predators and parasites, as shown by monthly censuses, February to September, 1947. Averages for seven citrus groves in Orange County, California.

The curve in figure 1 shows that the mealybugs began to increase rapidly in numbers in February, and that this rapid increase in population culminated in June. During the month of May the rate of increase of parasites far exceeded that of the mealybugs, and, for the same period of time, the rate of predator increase was also somewhat greater than that of the mealybugs. Consequently, the increase in mealybug population was arrested by June. The continued increase in predator numbers in June caused a sharp decrease in mealybug population, and by August the mealybugs were reduced to a population density of practical insignificance.

From these data it is extremely difficult to say whether parasites or predators were the more important mortality factor in 1947. It appears that both were important, perhaps together accomplishing control at a lower host density than would have been possible by either one alone. Predator populations built up later in 1947 than in 1946; this may account for the increase in parasitization in 1947 over that in 1946.

In the absence of planned experimental comparisons, such as insecticidal check tests (DeBach 1946, 1949), it is impossible to determine with any accuracy whether predators alone or parasites alone would have accomplished better control than both acting together. However, field observations indicate that during the later phases of the interaction predators were the dominant control factor which sharply reduced mealybug and parasite populations alike. In addition, evidence from certain tests involving the effects of insecticidal residues, especially chlordan, on mealybug and natural enemy populations indicates that the elimination of predators early in the cycle would permit a rapid increase of mealybugs even in the presence of a high degree of parasitization. The long-tailed mealybug population

was approaching proportions of minor economic importance in some of the groves studied by the time its increase was arrested by the action of its natural enemies in June.

Relative Abundance of Entomophagous Species.—The numbers in each of the main groups, predators or parasites, of the various species of natural enemies of the long-tailed mealybug recovered in the course of these studies indicate to some extent the relative importance of each as a control factor affecting mealybug populations.

Anarhopus sydneyensis was by far the most abundant of the parasitic species in 1947 (Table 1). It, along with its hyperparasite *Lygocerus* sp., comprised 74.9 per cent of the four principal species of parasites. *Tetracnemus pretiosus* represented 15.6 per cent, *Coccophagus gurneyi* 8.7 per cent, and *Tetracnemus peregrinus* 0.8 per cent of the total. The other species of parasites (see above) were rare. In comparison, in 1946 *Anarhopus* comprised 87 per cent of the parasites, *Tetracnemus pretiosus* 8 per cent, *Coccophagus gurneyi* 4 per cent, and *Tetracnemus peregrinus* 1 per cent. The relative status of the parasites did not change from 1946 to 1947, but *T. pretiosus* and *C. gurneyi* did increase somewhat at the expense of *Anarhopus*.

Table 1.—Relative numbers of principal parasites of the long-tailed mealybug in seven citrus groves in Orange County, California, 1947.

Month	*Anarhopus sydneyensis*[1]	*Tetracnemus pretiosus*	*Coccophagus gurneyi*	*Tetracnemus peregrinus*	Total
February	44	10	0	0	54
March	199	34	10	2	245
April	648	33	42	0	723
May	875	82	77	0	1034
June	3487	953	487	0	4927
July	1243	246	145	64	1698
August	36	0	0	0	36
September	11	0	0	0	11
Total	6543	1358	761	66	8728
Per cent	74.9	15.6	8.7	0.8	100

[1] Including hyperparasitized *Anarhopus sydneyensis* from which *Lygocerus* sp. emerged.

The brown lacewing, *Sympherobius californicus*, was the most abundant of the three principal species of predators recovered in these studies (Table 2), this species representing 48 per cent of the total. The green lacewing, *Chrysopa californica*, was nearly as common, comprising 41 per cent of the total. The lady beetle, *Cryptolaemus montrouzieri*, was third, representing only 11 per cent of the total. The other species of predators (see above) were rare. In comparison, in 1946 the brown lacewing comprised 74 per cent of the predators, the green lacewing 17 per cent, and *Cryptolaemus* 9 per cent.

Table 2.—Relative numbers of principal predators of the long-tailed mealybug in seven citrus groves in Orange County, California, 1947.

Month	*Sympherobius californicus*	*Chrysopa californica*	*Cryptolaemus montrouzieri*	Total
February	0	2	0	2
March	3	1	0	4
April	10	14	3	27
May	53	25	35	113
June	262	14	34	310
July	234	333	58	625
August	16	100	7	123
September	0	8	0	8
Total	578	497	137	1212
Per cent	47.7	41.0	11.3	100.0

Hyperparasites and Parasites of Predators.—The data on *Anarhopus sydneyensis* presented in table 1 include those individuals hyperparasitized by *Lygocerus* sp. This hyperparasite becomes abundant enough on *Anarhopus* to raise the question whether it seriously impairs the efficiency of the primary parasite. The relation between *Lygocerus* and *Anarhopus* is shown in table 3. These data reveal that at the peak of the mealybug population in June, 1947, 42.9 per cent of the mealybugs were parasitized by *Anarhopus*. Of the large number of *Anarhopus* present at this time, only 4.4 per cent were hyperparasitized by *Lygocerus*. From June to July there was a sharp decrease in mealybug population, due in great part to increased predator action. No doubt predator competition was largely responsible for the decreased efficiency of *Anarhopus* (19.6 per cent) at this time. The activity of *Lygocerus* evidently was not impeded, however, as it succeeded in parasitizing 59.5 per cent of the *Anarhopus* population recovered in July and 75 per cent of that recovered in August. The high degree of efficiency demonstrated by *Lygocerus* in August was probably chiefly due to the fact that the relatively large numbers of individuals produced during July were competing for a small number of hosts, since the mealybug population by this time was reduced to a very low density. Despite this high degree of parasitism by *Lygocerus*, *Anarhopus* parasitized 28.2 per cent of the ex-

Table 3.—Parasitization of the long-tailed mealybug by all parasite species and by *Anarhopus sydneyensis* alone, and hyperparasitization of *Anarhopus* by *Lygocerus* sp., in seven citrus groves in Orange County, California, 1947.

Month	Long-Tailed Mealybugs					Per Cent *Anarhopus* Parasitized by *Lygocerus* sp.
	Total	Total Parasitized[1]		Parasitized by *Anarhopus* Alone[2]		
		Number	Per Cent	Number	Per Cent	
February	213	54	25.3	44	20.7	0.0
March	1237	245	19.8	199	16.1	0.0
April	4732	723	15.3	648	13.7	8.0
May	5682	1034	18.2	875	15.4	16.3
June	8125	4927	60.6	3487	42.9	4.4
July	6348	1698	26.7	1243	19.6	59.5
August	107	36	33.6	36	33.6	75.0
September	39	11	28.2	11	28.2	27.3

[1] Including the parasites *Anarhopus sydneyensis*, *Tetracnemus pretiosus*, *Coccophagus gurneyi*, and *Tetracnemus peregrinus*.
[2] Including hyperparasitized *Anarhopus sydneyensis* from which *Lygocerus* sp. emerged.

tremely low mealybug population in September, and concurrently the proportion of *Anarhopus* parasitized by *Lygocerus* was reduced to 27.3 per cent.

The effect of the parasites of the brown and green lacewings on the efficiency of the lacewings as predators of the long-tailed mealybug is apparently not great. An examination of the data in table 4 will show that the populations of these predators were more affected by changes in host

Table 4.—Relative populations of the long-tailed mealybug and of its predators the brown lacewing, *Sympherobius californicus*, and the green lacewing, *Chrysopa californica*, and percentage parasitization of the predators, in seven citrus groves in Orange County, California, 1947.

Month	Long-Tailed Mealybugs	Brown Lacewings		Green Lacewings	
		Number	Per Cent Parasitized	Number	Per Cent Parasitized
February	213	0	0.0	2	0.0
March	1237	3	0.0	1	0.0
April	4732	10	20.0	14	17.0
May	5682	53	12.5	25	0.0
June	8125	262	14.5	14	28.0
July	6348	234	11.0	333	18.0
August	107	16	50.0	100	86.0
September	39	0	0.0	8	67.0

density than by the attacks of their parasites. Although 50 per cent of the brown lacewings were parasitized in August, and 86 per cent of the green lacewings were parasitized in August and 67 per cent in September, these high percentages of parasitization occurred after the mealybug population was reduced and there was insufficient food to maintain the large predator population.

DISCUSSION.—The general relationship of the several factors involved in the host-predator-parasite complex in 1946 and 1947 is somewhat different, both in time and in degree of development of populations. An examination of the curves in figure 2 in detail reveals several interesting variations in development of the 1946 and the 1947 populations.

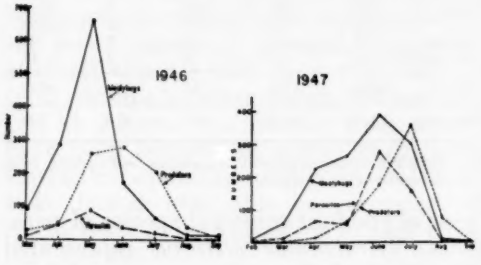

FIG. 2.—Relative changes in populations of the long-tailed mealybug, its predators and parasites, as shown by monthly censuses in citrus groves in Orange County: 1946, averages for ten groves; 1947, averages for seven groves.

In 1946 there was a large enough population of predators and parasites by May to arrest the increase of the mealybug population. Predators were a far more important factor than parasites in this respect. In 1947, however, the predator population had not developed in sufficient numbers by May to curtail the rate of increase of the mealybug population, which continued to develop rapidly until June. Due both to this relative freedom from predator competition and to the abundance of host material, the parasites were able to increase rapidly in numbers, so that by June the parasites were a more

important factor than they had been in 1946 in regulating further increases in the mealybug populations.

During May, 1947, however, the predator population began a rapid numerical increase which continued at an accelerated pace from June to July. By July the numerical value of the predator populations had far surpassed that of the parasites, and by August the combined action of predators and parasites had reduced the mealybug population to a density of practical insignificance.

The ability of the parasites to become an effective factor in control of long-tailed mealybug populations when relatively fre of predator competition has previously been demonstrated by DeBach (1946), who showed that by the application of certain insecticides and inert materials to the host plant a differential effect was produced on the predator-parasite complex. This effect was largely to eliminate the predators while having little if any effect on the parasites. Under such conditions the parasites increased concurrently with the mealybug populations and became more effective than in those cases where predator competition was a more important factor. The parasites did not, however, demonstrate the ability to regulate mealybug populations at as low a level as did the predators. The results of the 1947 studies, obtained under natural conditions, therefore corroborate the 1946 experimental findings.

Another variation which should be mentioned is the striking difference between the numerical ratios of brown to green lacewings recovered in the years 1946 and 1947. In 1946 the brown lacewing, *Sympherobius californicus*, comprised 74 per cent of the total population of the three principal predators; the lady beetle, *Cryptolaemus montrouzieri*, comprised 17 per cent; and the green lacewing, *Chrysopa californica*, 9 per cent. In 1947 the brown lacewing comprised 48 per cent, the green lacewing 41 per cent, and the lady beetle 11 per cent. A slow spring build-up of the brown lacewing in 1947 probably accounted for the ability of the green lacewing to get a better start in 1947.

Reference to table 2 will show that following the peak in mealybug numbers obtained in June, there was a marked increase in the numbers of green lacewings, whereas the number of brown lacewings recovered was actually reduced. This rather abrupt change in the numerical status of these two predators may be more readily understood when it is pointed out that the larvae of the green lacewing are larger and more voracious than those of brown lacewing, and have been observed to feed more or less indiscriminately on brown lacewing larvae and mealybugs in mixed populations. Therefore, it is very likely that the large population of green lacewing appearing in July developed partly at the expense of the brown lacewing population which had developed by June.

Despite the yearly variation in relative effectiveness of the various natural enemies, which has been pointed out in the preceding discussion, the final status of the biological control of the long-tailed mealybug in the groves studied was in general the same in 1947 as in 1946, that is, by mid-summer the populations of mealybugs were effectively controlled by natural enemies, with predators playing the most important role in the final subjugation of the pest.

Summary.—Populations of the long-tailed mealybug, *Pseudococcus longispinus* (Targ.), began to increase rapidly in February, 1947. This increase culminated in June, with peak populations in certain groves approaching minor economic proportions. The action of natural enemies, which was insignificant until May, reduced mealybug populations rapidly in July. By the end of August these populations were of no practical significance.

Six species of primary parasites, three species of secondary parasites, and eight species of predators were obtained from population samples of the long-tailed mealybug during 1947. The predator *Sympherobius californicus* Banks was attacked by one primary and one secondary parasite. Four primary parasites and one secondary parasite were reared from the predator *Chrysopa californica* (Coq.).

All information indicates that predators were the major factor in the final subjugation of mealybug populations. It is probable, however, that parasites were more important than predators early in the season. Mealybug parasites were considerably more abundant in 1947 than in 1946. Average parasitization in June amounted to 60.6 per cent, as compared

with 13.5 per cent during the mealybug peak in May, 1946. This may have been correlated with the late build-up of predators in 1947 and the corresponding lack of initial competition. The brown lacewing, *Sympherobius californicus*, was relatively less important in 1947 than in 1946, and the green lacewing, *Chrysopa californica*, was relatively more important. *Sympherobius* comprised 48 per cent of the common predators in 1947, *Chrysopa* comprised 41 per cent, and *Cryptolaemus montrouzieri* 11 per cent. Parasites of *Chrysopa* and *Sympherobius* did not appear to be limiting factors before mealybug populations had been adequately reduced.

Anarhopus sydneyensis Timb. was the dominant parasite of the long-tailed mealbug, comprising 75 per cent of the parasites reared. *Anarhopus* was commonly attacked by a secondary parasite, *Lygocerus* sp., but it is not clear that this had any pronounced effect on *Anarhopus* populations. It appeared more likely that *Anarhopus* populations were reduced by predator competition.

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Effects of Parathion on Plants

DAVID B. SCOTT, JR., *Oakland, Calif.*

With the continuing success in the use of such efficient new insecticides as parathion outside of purely agricultural fields, it is becoming increasingly urgent that phytotoxicological data be made available. Much has been done. This paper is intended primarily as a supplement to other information—principally with reference to sprays and dusts of parathion applied for pest control on ornamentals. Metcalf *et al.* (1948), Mitchell *et al.* (1949) and Pritchard (1948) have shown that extremely low percentages of parathion will do an efficient control job.

Over a period of 18 months during 1948 and 1949 trials have been conducted in the San Francisco Bay Area on outdoor-grown plants of an aggregate of 40 varieties of trees, shrubs, vines, perennials and two conifers to control aphids, mites, mealybugs, whitefly, immature scale insects and a species of *Argyresthia* attacking only conifers.

Parathion is currently supplied to the trade in 15 per cent and 25 per cent wettable powders, 1 per cent and 2 per cent dusts and a 10 per cent aerosol for greenhouse use. Without minimizing the inherent toxicity and hazards connected with its use, information is nevertheless accumulating to the effect that parathion is both less hazardous and less persistent than originally forecast. It is therefore conceivable that a liquid concentrate may appear, inasmuch as the extremely toxic tetraethyl pyrophosphate is sold for consumer use principally in liquid form. With that premise in mind, much of the test work outlined here was done with a liquid concentrate of parathion.

MATERIALS AND METHODS.—All plants listed were subject to the usual garden conditions to be found in any home garden with climatic variations similar to those of the San Francisco Bay Area—mild winters, morning fog, normal yearly rainfall of 18 to 20 inches, light to moderate sea breezes during Spring and Summer.

The parathion formulations used were as follows:

15 per cent parathion wettable powder
17 per cent parathion emulsifiable concentrate (isopropyl alcohol as carrier plus emulsifier)
2 per cent parathion dust

The sprays were applied by a carefully calibrated hand concentrate sprayer attached to a garden hose, and the dust by means of a small hand duster. Inasmuch as we are concerned here primarily with the effects on the plants, pest control

Table 1.—Phytotoxic investigations of .02 per cent parathion spray derived from 15 per cent wettable powder (1 lb. per 100 gals.).

PLANTS TESTED	SEASON FOR TREATMENT	INFESTATION TREATED	APPARENT PHYTOTOXICITY
Betula alba	Summer	Aphid-*Calaphis betulaecolens*	None
Chamaecyparis lawsoniana Ellwoodi	Spring	*Argyresthia* Sp.	None
Citrus—Lime	Spring	Black Citrus Aphid	None
Clematis paniculata	Fall	Mexican Mealybug	None
Rosa, Hybrid Tea[1]	Spring	Rose Aphid	Leaf burning at full dosage
Vinca minor	Spring & Summer	Aphid-*Rhopalosiphoninus latisiphon*	None
Sequoia gigantea	Spring & Summer	*Argyresthia* Sp.	None

[1] Two sprays with some leaf burning at full dosage.

Table 2.—Phytotoxic investigations of .02 per cent parathion sprays derived from 17 per cent liquid concentrate (1 pint per 100 gals.).

PLANT TESTED	SEASON FOR TREATMENT	INFESTATION TREATED	TOTAL SPRAYS IN 1948–49	APPARENT PHOTOTOXICITY
Abutilon Spp.	All Seasons	Melon Aphid, Whitefly-*Aleyrodes spiraeoides*	12	None
Aquilegia Spp.	Spring & Summer	Aphid-*Myzus aquilegiae*, Whitefly-*Aleyrodes spiraeoides*	3	Possible chlorosis
Aubrietia deltoides	Spring	Potato Aphid	2	None
Azalea indica—var.	Summer	Two-spotted Mite	2	None
Betula alba	Spring, Summer & Fall	Aphid-*Calaphis betulaecolens*	4	None
Bougainvillea Spectabilis	Summer	Bean Aphid	2	None
Camellia sasanqua—seedlings	Spring	Black Citrus Aphid	1	None
Campanula Raddeana	Winter	Aphid Sp. (?)	2	None
Citrus—Lime	Spring & Summer	Black Citrus Aphid, Immature Black Scale, Red Spider	4	None
Clematis paniculata	Fall	Mexican Mealybug	1	None
Daphne odora variegata	Summer	Aphid Sp. (?)	1	None
Escallonia montevidensis	Spring, Summer & Fall	Aphid Sp. (?)	5	None
Forsythia intermedia	January	Mexican Mealybug	1	Buds injured, possible delayed foliation
	Spring, Summer	Mites Sp. (?)	2	None
Fuchsia Spp.	Summer	Potato Aphid, Whitefly-*Aleyrodes spiraeoides*	4	None
Gentiana acaulis	Spring	Aphid Sp. (?)	1	None
Geranium Spp.	Spring & Summer	Mexican Mealybug, Aphid Sp. (?)	4	None
Gladiolus	Summer	Potato Aphid, Whitefly-*Aleyrodes spiraeoides*	4	None
Grapes—various	Summer	Two-Spotted Mite	2	Possible leaf chlorosis
Hedera canariensis	Spring & Summer	Ivy Aphid	2	None
Ilex aquifolium	Spring & Summer	Immature Black Scale, Mexican Mealybug, Aphid Sp. (?)	3	None
Iris Kaempferi	Spring & Summer	Whitefly-*Aleyrodes spiraeoides*, Potato Aphid	5	None
Iris spuria	Spring & Summer	Whitefly-*Aleyrodes spiraeoides*, Potato Aphid	5	None

Table 2—Continued

PLANT TESTED	SEASON FOR TREATMENT	INFESTATION TREATED	TOTAL SPRAYS IN 1948–49	APPARENT PHOTOTOXICITY
Laburnum vossi	Fall-Dormant	Mexican Mealybug	1	Some terminal buds killed—extensive delayed foliation
	Summer	Two-Spotted Mite	3	None
Lagerstroemia Spp.	Summer	Aphid Sp. (?)	2	None
Leontopodium alpinum	Spring	Potato Aphid	1	None
Lilium Spp.	Early Spring	Crescent-marked Lily Aphid	2	None
Lotus Berthelotii	Fall	Mexican Mealybug	1	Tip burn, one plant died—cause not determined
Lupinus—Russell	Spring, Summer & Fall	Aphid-*Macrosiphum albifrons*, Two-Spotted Mite	Every 14 days	Burn if sprayed late in day—otherwise none
Tropaeolum majus (Nasturtium)	Fall & Summer	Bean Aphid	3	None
Potentilla Spp.	January	Strawberry Aphid	1	None
Primula polyantha	Spring	Aphid Sp. (?)	2	None
Primula Sieboldi	Spring	Aphid Sp. (?)	2	None
Pyracantha Spp.	Summer & Fall	Green Apple Aphid	4	None
Rosa—Hybrid Tea	Spring, Summer & Fall	Rose Aphid, Red Spider	Every 14 days	Severe burn if at full dosage or too late in day—no injury at ½ dosage
Sequoia gigantea	Spring & Summer	*Argyresthia* Sp.	3	None
Syringa—lilac	Fall-Dormant	Mexican Mealybug	2	Terminal buds injured
Vinca Minor	Spring & Summer	Aphid-*Rhopalosiphoninus latysiphon*	4	None

evaluation percentages are not given in the tables. However, it is necessary to state that for all pests listed in the tables except *Argyresthia*, control was excellent, though frequent repeat applications were required for most species of aphids and whiteflies.

Sprays were applied on the basis of one pound of 15 per cent wettable powder per 100 gallons of water which is the probable minimum dosage consistent with requirements for pest control. One pint of the 17 per cent liquid concentrate is equivalent to one pound of the wettable powder.

As stated above, frequent repeat applications were necessary for several species of aphids and whiteflies—most particularly *Macrosiphum albifrons* on

Table 3.—Phytotoxic investigations of 2 per cent parathion dust applied to plants.

PLANT TESTED	SEASON	INFESTATION	TOTAL SPRAYS APPLIED 1948–49	APPARENT PHYTOTOXICITY
Aquilegia Spp.	Summer	Whitefly-*Aleyrodes spiraeoides*	2	None
Bell Pepper	Summer	Whitefly-*Aleyrodes spiraeoides*	4	None
Bougainvillea Spectabilis	Summer	Bean Aphid	1	None
Chamaecyparis Lawsoniana Ellwoodi	Spring	*Argyresthia* Sp.	1	None
Clematis paniculata	Fall	Mexican Mealybug	1	None
Lupinus polyphyllus	Spring & Summer	*Macrosiphum albifrons*	5	Burn when moisture hit dust
Tropaeolum majus (Nasturtium)	Summer & Fall	Bean Aphid	4	Burn when moisture hit dust
Potentilla Sp.	Fall	Strawberry Aphid	1	None
Pyracantha Sp.	Summer	Aphid Sp. (?)	2	None

lupines, melon aphid, rose aphid and whitefly. The rapidity of buildup in several instances necessitated as many as 18 applications between January 1948 and April 1949. Further observations may reveal that the rapid repopulation can be attributed to insufficient dosages.

DISCUSSION OF RESULTS.—The data in table 1, based on the use of 15 per cent wettable powder of parathion, are limited crosschecks, as stated previously, against the 17 per cent liquid concentrate. Much of the work done thus far on ornamentals (Pritchard 1948 *et al.*) has indicated that one pound of 15 per cent wettable powder performs quite well on most plants with a minimum of injury, which is correlated fairly well here. It appears that roses are sensitive to parathion, especially to .02 per cent parathion sprays or higher, or when the spray is applied too late in the day for the leaves to dry thoroughly by nightfall. An equivalent of 0.5 pound of 15 per cent wettable powder per 100 gallons (.01 per cent parathion) did not injure roses when applied by midday.

Table 2 contains the most significant data on the use of 17 per cent parathion liquid concentrate on the majority of the plants concerned in these trials.

Here the first real signs of severe injury appeared when dormant deciduous plants were sprayed. The injuries occurred on *Laburnum*, *Forsythia* and *Syringa*. It is interesting to note that all three types have light terminal buds into which the spray penetrated and probably remained for some time. Similar symptoms appeared on all three, e.g., killed or injured buds and delayed foliation. Sprays applied to these varieties during the active growing season, however, produced no detectable injury. Though no check was run on straight isopropyl alcohol, it is unlikely that the inclusion thereof in this formulation would have phytotoxic effects.

Leaf burn appeared on *Lupinus* and roses when spray was applied too late in the day, particularly on the latter. No observations were made on lower dosages of liquid concentrate. *Lotus Berthelotii* suffered severe tip burn after one application, and one plant died completely, though it was not determined that the spray was responsible. Some leaf burn and a condition resembling chlorosis appeared on *Aquilegia* and Thompson Seedless grapevines following the spraying. On the other hand, three varieties of *Abutilon* received 12 applications with no apparent signs of injury.

Limited observations of the effects of a 2 per cent parathion dust are summarized in table 3. Injury appeared only when excessive amounts of dust were wet by dew on the leaves of *Nasturtium* and *Lupinus*.

CONCLUSIONS.—Until more data become available, the use of any parathion formulations on ornamentals should be limited to evergreen plants and deciduous plants in full growth. Fall and Winter applications to dormant plants—deciduous or evergreen—with tight terminal buds, *e.g.* species of *Magnolia* (deciduous), Grapes, *Camellia*, *Daphne*, *Rhododendron*, *Azalea*, *Syringa*, *Forsythia* and deciduous trees, should be avoided until more test work is completed and verified. On the majority of plants and pests under investigation control was safe and satisfactory at the .02 per cent parathion concentration.

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Dr. B. E. Montgomery, Associate Professor of Entomology of Purdue University, has been granted a year's leave to go to New Zealand under a fellowship granted under the Fulbright Act. Doctor Montgomery will study the bumblebees of New Zealand.

Philip Luginbill, Jr., who has completed work for his doctorate at Purdue University, has accepted a position on grasshopper control with the Bureau of Entomology & Plant Quarantine and will be stationed at Madison, Wisconsin.

Contact Toxicity of Several Formulations of DDT to First Instar Oriental Fruit Moth Larvae[1,2]

A. A. LaPlante Jr.[3] *New York State Agr. Expt. Sta., Geneva*

Although DDT was first used in 1943 (Driggers 1946) for control of the oriental fruit moth, *Grapholitha molesta* (Busck), on peaches, very little of the data has been obtained from research under laboratory conditions. This is to be expected, inasmuch as field application is the ultimate test of the value and efficiency of any control measure directed against pests of agricultural crops. There are, however, certain fundamental aspects which are difficult to evaluate in the field. One of these aspects is the comparison between different formulations of the same material. A further problem is the precise method by which an insecticide brings about mortality, in other words, does DDT cause the death of newly hatched larvae by contact action, by being ingested or by a combination of the two factors?

Experimental Methods.—This study was designed primarily to evaluate the toxicity of four distinct formulations of DDT under laboratory conditions to first instar oriental fruit moth larvae. The four formulations used in the tests were: (1) an emulsion of DDT using benzene as the solvent and a phthalic glycerol alkyd resin[4] as the emulsifier, (2) a 50 per cent DDT commercial wettable powder,[5] (3) dusts containing 0.5 per cent and 3 per cent concentrations of DDT[6] with talc[7] as the diluent and (4) pure crystalline DDT (melting point 107–108° C.).

The DDT emulsion was prepared by dissolving 10 grams of pure, para-para DDT in 100 ml. of chemically pure benzene to make a stock solution. Twelve ml. of the stock solution were mixed with a small amount of water and 0.15 ml. of the emulsifier was added. This mixture was then pumped through a hand homogenizer several times. The total volume was then brought up to a liter by the addition of water. The resultant emulsion was the equivalent of a field concentration of a pound of actual DDT in 100 gallons of water emulsified with 2 oz. of emulsifier. The emulsifier made a stable, milky-white emulsion.

The wettable powder spray mixture was prepared in gallon lots at a concentration equivalent to one pound of actual DDT in 100 gallons of water with 2 oz. of emulsifier added to increase the spreading properties. A total of 9.1 grams of 50 per cent wettable powder was incorporated with a quart of water to which had been added 0.55 ml. of emulsifier. A laboratory stirrer was placed in operation and enough tap water was added to make a gallon of suspension. All spraying operations were accomplished with a stationary paint spray gun[8] with a No. 19 nozzle opening operating at 18 pounds pressure per square inch. The actual spraying was done by means of a settling tower technique.

The dust mixtures were prepared by incorporating the proper amount of 50 per cent DDT powder without wetting agent with talc as the diluent. The dusts were mixed by two distinct methods. In the first method a small hand mortar was used to make up 50 grams of the total dust. In the second method a standard ball mill was used to mix 10 pounds of total dust. The dusts were mixed for periods of 10 minutes by hand and one hour in the ball mill. The author felt that a comparison between these two types of dust preparation would be of value in collating field and laboratory data. The test surface was then dusted by means of a settling tower technique using a hand bulb to propel the dust from a 125 ml. Ehrlenmeyer flask through a glass nozzle.

In one series of tests, deposits of pure crystalline DDT were prepared on microscope slides in two ways. The first preparation was made by carefully warming the crystals to the melting point and then allowing them to solidify with the result that a comparatively smooth surfaced deposit was formed. The second preparation

[1] A digest of a thesis submitted to the Graduate School of Cornell University Feb. 1949 in partial fulfillment of the requirements for the Ph.D. degree.

[2] Journal Paper No. 790, New York State Agricultural Experiment Station, December 29, 1948.

[3] Now Extension Entomologist.

[4] *Triton B1956* manufactured by the Rohm and Haas Co.

[5] *Deenate 50-W* manufactured by the E. I. duPont de Nemours Co., Inc.

[6] The stock mixture used in preparing the dusts was *Deenate 50-P*, also manufactured by the E. I. duPont de Nemours co., Inc.

[7] *Loomkill*. Manufactured by the W. H. Loomis Talc Corp.

[8] *De Vilbiss Type WDA*.

was made by warming the crystals between a microscope slide and a cover slip, allowing the crystals to solidify, and then reheating the cover slip slightly so that it could be removed. This treatment resulted in a comparatively rough surfaced deposit.

In order to study the contact toxicity of DDT sprays and dusts, it is generally recognized that the use of a plant surface for the tests might more closely approach field results. On the other hand, the variables and difficulties encountered in using a plant surface in this type of study might result in considerable error. The writer believes that it is essential to have a smooth, unbroken test surface, as newly hatched larvae tend to stop crawling and explore any uneven portion of the surface, and the uneven section may have a greater deposit of insecticide than a smooth unbroken surface. Another problem is the difficulty of keeping the larvae on the treated surface for several minutes without undue handling. If all parts of a peach twig could be uniformly and accurately coated with an insecticide, the problem would be relatively simple. It would, however, be a tedious and painstaking task to make an accurate determination of deposit per unit area because of the variation in size of leaves and twigs and would be subject to error without special equipment and procedures.

For the purpose of this study, therefore, a microscope slide and cover slips made of glass were used as the test surfaces. The rectangular cover slips (25 mm. × 40 mm.) were supported by 2 micro needles laid flat on a standard microscope slide (25 mm. × 75 mm. × 1 mm.). The slide bearing the cover slip was then sprayed or dusted until the desired deposit by weight had been obtained. The cover slip was then turned over and the opposite side was sprayed or dusted. The cover slip was then supported on 5 upright micro needles. This arrangement allowed the larvae to move at will on both the upper and lower surface of the cover slip and consequently the larvae would remain in contact with the toxicant for the desired time interval without further handling. After treatment, the larvae were removed to 0.5 oz. shell vials in which had been placed a centimeter-square cube of peeled green apple. Two larvae were placed in each vial and a ring of tanglefoot was deposited around the lip of the vial. Only 5 larvae were caught in this barrier in all of the tests in which this method was used. Examinations were made 48 to 72 hours later by slicing up the apple cubes with a fine scalpel under a low power binocular microscope and determining the number of larvae which had successfully entered the food medium. All of the contact toxicity studies were conducted within a large constant temperature and humidity chamber maintained at a temperature of 80°F. and 70 per cent relative humidity.

In a series of ingestion experiments, Rome Beauty apples were used as the test surface. The apples were prepared by thoroughly scrubbing them in a detergent solution and then slicing them in half. One half of each apple was treated and the twin half was designated as check. The apple halves were then circled with a a tanglefoot barrier placed about one-half inch above the cut surface. Squares of wax paper bearing eggs in all stages were then mounted on the apple cheek by means of an insect pin in such a manner that one corner of the wax paper touched the surface of the apple. The paired apple halves were then placed in a constant temperature chamber maintained at 80°F. and 80 per cent relative humidity for further development. This method of testing is a modification of a method developed by Harris & Waters (1943) for the study of codling moth larvicides.

EXPERIMENTAL RESULTS.—*Pure DDT*—A total of four replicates of 10 larvae each were used to evaluate the toxicity of the two different preparations described in the section on methods. Larvae were exposed to the treated surfaces for periods of 45, 90, 135 and 180 seconds. Check larvae were handled exactly as were the treated larvae with the exception that an untreated glass surface was used. The results obtained in this test are summarized in table 1. It is apparent from these two tests that the second method of preparing the DDT resulted in a considerably higher toxicity to newly hatched larvae of the oriental fruit moth. Visual examination of the first preparation of DDT showed many small, apparently flat crystals. These crystals, however, were oriented in such a manner as to give the appearance of a relatively smooth and continuous covering over the entire deposit. The contrast shown in the second preparation was

Table 1.—Contact toxicity to newly hatched oriental fruit moth larvae on smooth surfaced and rough surfaced preparations of pure crystalline DDT.

Period of Contact in Seconds	Smooth Surface	Check	Rough Surface	Check
	No. of larvae alive			
15	31	39	1	39
45	32	40	0	38
60	31	40	0	40
120	20	37	0	39
	No. of larvae dead			
15	9	1	39	1
45	8	0	40	2
60	9	0	40	0
120	20	3	40	1
	Per cent mortality			
15	22.5	2.5	97.5	2.5
45	20.0	0.0	100.0	5.0
60	22.5	0.0	100.0	0.0
120	50.0	7.5	100.0	2.5

marked. Many of the crystals projected out from the surface giving a roughened irregular aspect to the entire deposit.

Benzene-DDT Emulsion.—The DDT crystals formed on a glass surface after a spray deposit has dried are irregular aggregates as shown in Fig. 1. The crystals adhere firmly to the glass surface and are not disturbed by the larvae crawling over them. Observation of newly hatched larvae under the microscope shows that some of the tarsi and prolegs of the larva are in contact with crystals at all times. The cover slips used in this test were sprayed with the emulsion so as to deposit 1.89 micrograms of DDT per square centimeter. A total of 3 replicates of 40 larvae each were exposed to the treated surface for a period of 30 minutes at 80°F. and 70 per cent relative humidity. The writer assumed from field observation that a period of 30 minutes would be sufficient for a larva to traverse the distance from the egg from which it had hatched to the tip of the peach twig. Mortality counts made at the completion of the test, 72 hours later, revealed that 13 larvae had died out of a total of 120 larvae in the 3 replicates, a mortality of 10.8 per cent. Out of the 120 larvae allowed to crawl over an untreated surface simultaneously with the test larvae, 6 were found dead at the completion of the test, a mortality of 5.0 per cent. This negligible

Fig. 1.—Deposit of DDT formulated as an emulsion showing crystals and supercooled droplets of DDT.

mortality indicates that the type of crystal formed is relatively non-toxic to newly hatched oriental fruit moth larvae under the conditions of this test.

When DDT is dissolved in a solvent such as acetone or benzene, a certain portion will not crystallize out upon evaporation of the solvent but will remain in a liquid or "supercooled" state. Practically speaking, it is believed by the writer that the amount of supercooled material would not interfere with the tests as they were run here because an actively crawling larva will walk over supercooled and crystalline DDT at random. This supposition was borne out in the following test. A cover slip which had been sprayed 8 weeks previously and kept at 80°F. and between 30 and 40 per cent relative humidity was still found to bear about the same quantity of supercooled DDT as it has immediately after spraying. This slide had been used within a few days of spraying in the test reported above. A total of 48 larvae were exposed in groups of 6 for a period of 30 minutes at 80°F. and 70 per cent relative humidity. After 48 hours of development, 2 larvae out of the 48 in the test had died. Out of 48 check larvae allowed to crawl over an unsprayed surface at the same time, 4 had died at the end of 48 hours. This evidence indicates that under the above conditions, the supercooled DDT had little or no effect on larval mortality.

Wettable Powder.—In preliminary tests at 80°F. and 70 per cent relative humidity, deposits of 15.06 and 7.53 micrograms of DDT per square centimeter showed complete mortality at exposure periods of 10 minutes or longer. Notes taken at the times of exposure to the

sprayed surface reveal that at the end of 30 minutes, 18 out of the 30 larvae had stopped crawling actively and appeared to develop tremors at the lower concentration. At the higher concentration, 27 out of 30 larvae had symptoms of severe irritation at the end of 17 to 18 minutes. Apparently the development of symptoms evidenced by irritation had no effect on eventual mortality as all larvae died whether or not symptoms of irritation had been exhibited.

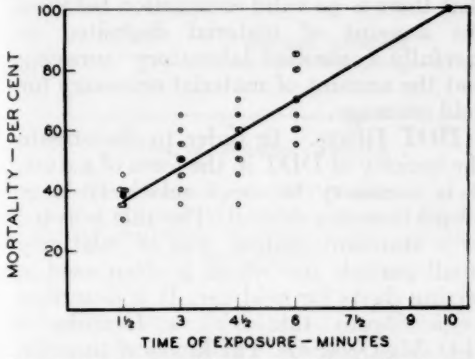

Fig. 2.—Contact toxicity of DDT formulated as a wettable powder at a deposit of 1.89 micrograms of DDT per square centimeter to newly-hatched oriental fruit moth larvae.

The amount of DDT per unit area was reduced in the next test to 1.89 micrograms of DDT per square centimeter. A total of 9 replicates of 20 larvae each were exposed to the treated surface for periods of 1.5, 3, 4.5, 6 and 10 minutes. Each replicate was run on an individually sprayed cover slip. A toxicity curve derived from an average of all replicates is shown in figure 2. A photomicrograph showing an average deposit is presented in figure 3. The data, as presented in figure 2, indicate that a mortality of 50 per cent is brought about by a contact period of 3 minutes and 45 seconds. Complete mortality occurs when the larvae are exposed to the sprayed surface for periods of 10 minutes or longer. The results of the test on the untreated surface showed that 704 larvae successfully entered the apple cubes out of a total of 720 in the test resulting in a mortality of 2 per cent. Observation of larvae after placement in the vial shows that many larvae crawl around the vial for from 15 minutes to 6 hours and longer before entering the apple cube. It was also noted that particles of deposit adhere to the larvae, thus coming into contact with parts of the larva other than the walking surfaces and thereby increasing the total frequency of contact with DDT crystals. It may be argued that the particles adhering to the larval body would introduce an error. The evidence, however, clearly shows that mortality is brought about by contact with the actual surface treated with DDT.

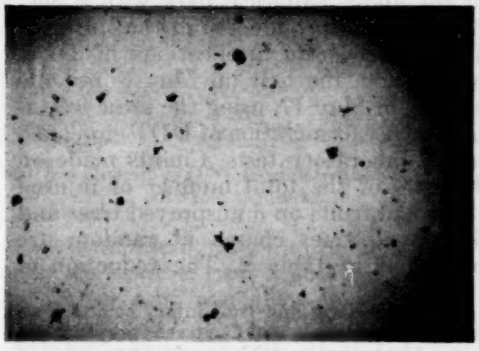

Fig. 3.—Deposit of DDT formulated as a wettable powder.

Correlation of Field and Laboratory Data.—The egg of the oriental fruit moth is often deposited a considerable distance from the tip of the twig. This fact was recognized as early as 1917 by Garman who indicated that the egg or earlier larval stages were probably the most vulnerable in the life history of the insect because of the position of the egg and its distance from the initial feeding ground of the larva. Measurement of 14 twigs on unsprayed 3 year old Elberta trees in the spring of 1947 showed an average distance of 9.5 inches from the egg to the tip of the twig. The distance varied from 3.5 inches to 16.4 inches. Under laboratory conditions of 80° F. and 70 per cent relative humidity, a total of 20 newly hatched larvae were able to crawl an average distance of 1.3 inches per minute on a glass surface. In other words, it might be expected that the average newly hatched larva would take 7.3 minutes to travel the average distance of 9.5 inches at 80°F. based on the assumption that the larva crawls directly from the egg to the tip of the twig by way of the shortest possible distance. Observations in the field indicate that this assumption is generally true.

In correlating the above information with the toxicity data in figure 2, it becomes apparent that a contact period of 7.3 minutes, as interpolated from the graph, would result in a mortality near 78 per cent under the conditions of the test. It is interesting to note the close agreement of the above empirical data with a field demonstration conducted in the spring of 1947. Two spray applications of DDT were made, the first on May 6 and the second on May 17, using the same wettable powder formulation of DDT employed in the laboratory tests. Counts made on June 28 of the total number of injured twigs and fruits on 5 unsprayed trees and 5 sprayed trees chosen at random are presented in table 2. The reduction of

Table 2.—Twig and fruit injury counts from five unsprayed trees and five trees sprayed twice with a 50 per cent wettable powder formulation of DDT at the rate of two pounds of powder in 100 gallons of water.

	No. of Injured Twigs	No. of Larvae in Twigs	No. of Injured Fruit	No. of Larvae in Fruit
Unsprayed	104	13	25	12
Sprayed	30	1	3	3
Per Cent Reduction	77.6	93.0	89.3	80.0

77.6 per cent of the number of infested twigs is remarkably close to the empirical mortality derived from the contact tests in the laboratory (about 78 per cent) with a deposit of 1.89 micrograms of DDT per square centimeter. The per cent reduction in the number of larvae in the twigs is not comparable, as it is not known whether larvae were killed by the DDT or had merely completed development and left the twigs in order to pupate. It is realized by the writer that this correlation between the two types of data may be entirely due to chance, as the particular weather conditions during the period of the field test may have been of such a nature as to bring about an apparent correlation between the two. The condition and vigor of the trees have not been carefully controlled nor has a large enough sample been taken in the field. It is of interest to note that the quantity of DDT deposited on the microscope slides as a wettable powder in the laboratory (at an equivalent rate of 2 pounds of 50 per cent wettable powder in 100 gallons of water and an actual DDT deposit of 1.89 micrograms per square centimeter) is equal to a field application of about 0.15 gallon per tree, assuming a 20 foot distance between peach trees with 110 trees to the acre. The average number of gallons applied to trees similar in size to the ones used in the above field tests is from 4 to 5 gallons per tree. It is recognized by the writer that there is no valid comparison between the amount of material deposited in carefully controlled laboratory spraying and the amount of material necessary for field coverage.

DDT Dusts.—In order to investigate the toxicity of DDT in the form of a dust, it is necessary to use a relatively large proportion of a diluent. The talc selected as a standard diluent was of relatively small particle size which is often used in mixing dusts for field use. It is described as a fibrous talc with a formula of $H_2O \cdot Mg_3O_2 \cdot 4SiO_3$. The limits of time did not allow for a study of more than one dilution.

In preliminary tests, cover slips were dusted with an actual DDT deposit of 3.20 micrograms per square centimeter. A total of four replicates were run on separate cover slips using 10 larvae in each replicate. Larvae were exposed to the toxicant for periods of 10, 20 and 30 minutes. At the end of 48 hours, and examination showed that all of the 120 larvae in the test had died. Check larvae run on clean cover slips for the same periods of time gave the following results: 6 larvae died and 114 successfully entered the apple cubes.

In the next series of tests, a 3-per cent DDT mortar mixed dust formulated with talc as the diluent was used. The result of five replicates of treated larvae exposed to five individually dusted cover slips is shown in figure 4. A photomicrograph of an average deposit is presented in figure 5. This test differed in several respects from the one in which a wettable powder formulation of DDT was used. The number of replicates was reduced to five, involving a total of 80 insects at each contact period. The number of insects in each replicate was not constant due to production difficulties and the number of larvae in each loomkill talc and each check replicate was reduced from 20 to 10 larvae. The fine (#3) camel's hair brush used to manipulate the larvae was washed frequently in benzene in order to remove any contaminating material that may have adhered to

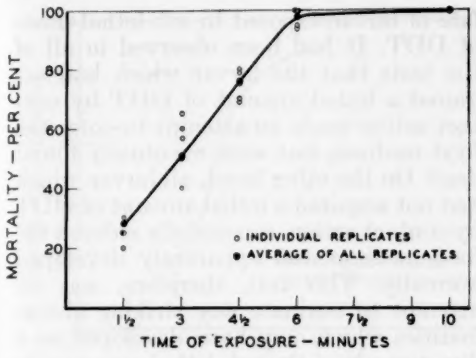

Fig. 4.—Contact toxicity of DDT formulated as a 3% dust at a deposit of 1.89 micrograms of DDT per square centimeter to newly-hatched oriental fruit moth larvae.

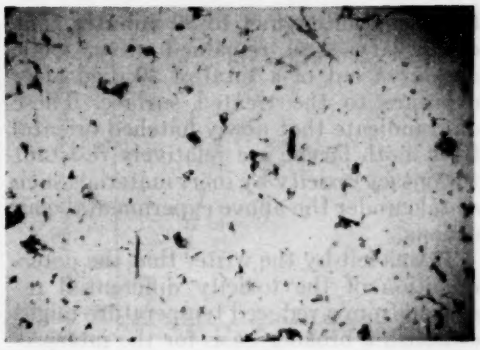

Fig. 5.—Deposit of DDT formulated as a 3% dust with talc as diluent.

the brush. The order followed in removing the larvae was: DDT, talc and check so that if contamination was a factor the checks would serve as an index if this factor were interfering with the tests.

Inasmuch as the prepared dust is composed of 94 per cent talc, 3 per cent of other diluents and 3 per cent DDT, it is interesting to note that the talc alone is relatively non-toxic under the conditions described here. A total of 200 larvae exposed to the talc deposit resulted in a mortality of 2.5 per cent at the completion of the test indicating that the toxicity observed in figure 4 is due solely to the contact action of the DDT under the above conditions. A total of 200 check larvae exposed to untreated glass cover slips showed a mortality of 1.0 per cent.

The point of 50 per cent kill is very close to 3 minutes which is similar to the results obtained in the wettable powder tests presented in figure 2. The rapidity of kill, however, is somewhat greater. This fact indicates that total contact frequency is acting here to result in a greater kill at increased periods of contact. Observation while larvae are crawling over the dusted surface reveals that many particles of material adhere to all parts of the larva and are carried on the larva to the vial. Here again, if the adhered DDT were acting on the larvae to such an extent as to impair the accuracy of the results, it might be reasonably expected that the toxicity of the dust would show a higher mortality than the wettable powder test throughout the entire curve. However, it may be observed that the toxicity curves of the wettable powder and the dust tests cross one another near a point representing 50 per cent mortality. Furthermore, the particle size of the DDT in both the wettable powder and the dust formulation is similar, indicating that the single factor of total contact frequency is primarily responsible for the differences in toxicity observed between the two formulations.

The deposit of 3 per cent dust used in the laboratory tests at an actual DDT concentration of 1.89 micrograms per square centimeter is equivalent to a field application of about 5.5 pounds per acre, or 0.05 pound per tree on the basis of the average number of trees per acre discussed in the section on correlation of field and laboratory data. The average amount of dust applied to trees of this size in field dusting operations on peaches is from 0.5 to 0.75 of a pound per tree. It is generally considered that under field conditions, three dust applications are the equivalent of two spray applications (Wheeler & LaPlante 1948). It is therefore seen that the results of these laboratory tests might indicate that if deterioration due to weathering factors were equal, the two formulations would probably have equal toxicity under field conditions. These results also support the contention that proper timing of a dust application would result in as good control of newly hatched oriental fruit moth larvae as would result from a properly timed spray application under conditions of mild weathering.

In order to determine whether the talc would be toxic if larvae were allowed to remain in contact with it for a longer period of time, a test was run using talc alone and with a check, and increasing

the period of contact to 30 minutes. The check larvae all remained alive, while one larva out of a total of 30 died after exposure to the treated surface. These data indicate that newly hatched oriental fruit moth larvae are relatively resistant to contact toxicity by inert materials such as talc under the above experimental conditions.

It was felt by the writer that the determination of the toxicity differential resulting from a reduced temperature might establish a broader basis for the interpretation of data obtained in the field. Sweetman (1945) attempted an evaluation of this factor under laboratory conditions.

Table 3.—Contact toxicity of three-per cent DDT dust formulated with talc at a deposit of 1.89 micrograms of DDT per square centimeter. Test conducted at 65° F. and 70 per cent R.H.

Period of Contact in Minutes	Per Cent Mortality—3% DDT	Per Cent Mortality—Check
1.5	71.3	3.3
3	85.7	6.6
4.5	88.3	0.0
6	100.0	0.0

He used the firebrat, *Thermobia domestica* (Pack.), as the test insect and studied the influence of moisture and temperature on the residual kill of DDT in laboratory constant temperature chambers. He found that a 3-per cent dust, using pyrophyllite as the diluent, resulted in higher mortality to firebrats at 27°C. than at 37°C. at similar relative humidities of 70 per cent and 68 per cent respectively. To determine if this relationship existed with newly hatched oriental fruit moth larvae, a test was conducted under conditions of 65°F. and 70 per cent relative humidity. The results are shown in table 3. A total of 10 larvae were utilized in each of 3-replicates. A comparison of these figures with similar figures obtained at 80°F. shows that by lowering the temperature 15°F., while other factors were held constant, an increase in the toxicity of the 3-per cent DDT dust was brought about. As is true with many biological phenomena of this nature, the increase was more pronounced at shorter periods of contact than at longer periods of contact.

Effect of Sub-Lethal Doses.—This test was designed to probe further into the fate of larvae exposed to sub-lethal doses of DDT. It had been observed in all of the tests that the larvae which had acquired a lethal amount of DDT by contact action made no attempt to enter the food medium, but were eventually found dead. On the other hand, all larvae which had not acquired a lethal amount of DDT by contact action, successfully entered the food medium and apparently developed normally. This test, therefore, was an attempt to evaluate any striking abnormalities which may have developed as a direct result of the sub-lethal exposure to DDT.

A qualitative test was conducted utilizing 400 check larvae and 411 larvae which had been exposed to a 3-per cent DDT dust for a period of 3 minutes. As indicated in figure 4, this period of contact had been shown to result in about 50 per cent mortality under the same conditions of temperature and humidity observed in this maturity test. Each group of larvae was placed in a battery jar containing a supply of green apples upon which to feed and provided with a strip of corrugated paper within which to pupate. From the jar of check larvae a total of 117 moth emerged, depositing 757 eggs of which 553, or 73.1 per cent hatched. From the jar of treated larvae, a total of 99 moths emerged, depositing 1796 eggs of which 1455, or 82.2 per cent, hatched. While the test was in progress, the question arose as to whether sex ratio might be the factor controlling the quantities of eggs produced by each group of moths. Counts were made at the end of 4 days, and showed that 29 moths in the check group had deposited 256 eggs. Of these 29 moths, 19 were females and 10 were males. A group of 25 treated moths had deposited a total of 593 eggs within the same period of time. Of these 25 moths, 12 were females and 10 were males. It does not seem wise to the writer to draw any conclusions from the simple test outlined above. There are many uncontrolled factors operating to influence the results of a test under the above conditions. The indications are, however, that moths which have developed from larvae receiving a sub-lethal dose of DDT by contact deposited over twice as many eggs as moths developing from untreated larvae.

Contact *vs.* Ingestion Toxicity.—One of the objects of this investigation

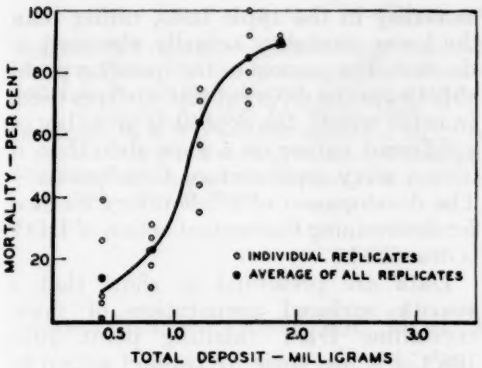

Fig. 6.—Interaction of contact and ingestion toxicity of talc to newly-hatched oriental fruit moth larvae.

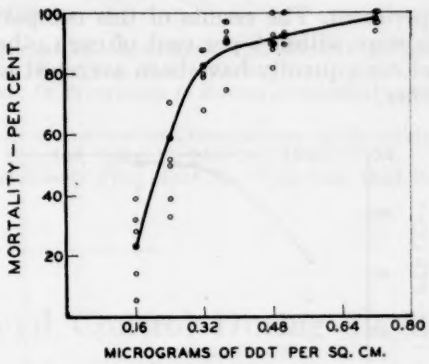

Fig. 7.—Interaction of contact and ingestion toxicity of 0.5% DDT dust with talc as diluent to newly-hatched oriental fruit moth larvae.

was to determine the mode of action of DDT on the newly hatched larva. Specifically, is the mortality observed under orchard conditions primarily due to contact action, to ingestion of the material or to a combination of the two factors? In order to study this relationship, experiments were conducted using Rome Beauty apples as the test medium and dusts containing 0.5 per cent and 3.0 per cent DDT incorporated with talc as the test insecticides. The toxicity of talc alone was also compared with the DDT dusts to determine what part of the total toxicity could be ascribed to the diluent.

A series of five talc deposits were tested. A total of five apple halves were dusted at one time, employing a settling tower technique. Each apple half was then considered to be a replicate. The test was conducted at 80°F. and 80 per cent relative humidity and involved a total of 1066 treated larvae and 908 check larvae. The results of this test are presented in graphic form in figure 6. A comparison between the mortality observed after 30 minutes to the talc in the contact studies (2.5 per cent) and the mortality observed in this ingestion test reveals that at the same deposit of talc (1.2 milligrams per microscope slide) the mortality has been increased to 64 per cent. The apple surface is probably comparable to a peach twig under field conditions in the following way. If the dust deposit irritated the larva under field conditions, the larva would have the opportunity to fall from the peach twig, whereas under the conditions of this test, the larva would fall into the tanglefoot barrier. It might be expected that if excessive irritation, characterized by rapid uncoordinated movement had taken place, many more larvae would have been found caught in the tanglefoot on the treated apple halves than would be found on the untreated apple halves. Examination of the data shows that the following percentages of larvae were caught in the tanglefoot barrier on the treated apple halves reading from the lowest concentration of talc in figure 6 to the highest concentration respectively: 60.9, 47.1, 42.6, 39.0 and 32.4 per cent. The corresponding figures for the check apple halves were: 44.1, 39.3, 52.7, 51.5 and 55.3 per cent. This comparison shows that despite the decrease in per cent caught at the higher concentrations of talc, little weight can be given to the factor of irritation because of the divergence among the checks. The mortality observed in figure 6 is therefore probably due to the toxic effects of the talc.

An examination of figure 7 in which 0.5 per cent DDT has been incorporated with the talc shows that comparatively little increase in mortality accrued from the addition of 0.5 per cent DDT to the talc. Figure 8 shows the results of adding 3 per cent DDT to the talc. The increase in toxicity at equivalent deposits of material is more noticeable at lower concentrations, than at higher concentrations but the data indicate a higher toxicity throughout the range of deposits. A comparison was made with both dusts as regards the method of mixing. Each dust was mortar-mixed for use in part of the experiment and a separate quantity was ball milled for used in another part of the

experiment. The results of this comparison were within 3 per cent of each other and consequently have been averaged together.

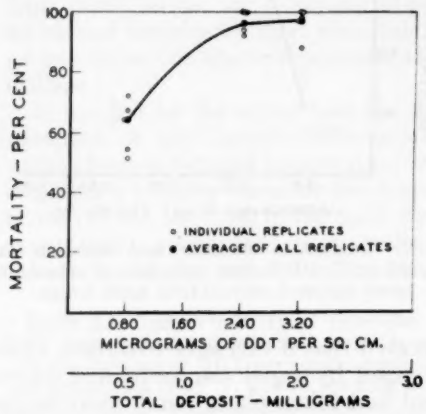

FIG. 8.—Interaction of contact and ingestion toxicity of 3% DDT dust with talc as diluent to newly-hatched oriental fruit moth larvae.

In comparing figure 8 with figure 4, evidence can be found to support the contention that contact action alone is sufficient to cause the high mortalities observed in the ingestion test. The toxicity curve in figure 8 indicates that a mortality of near 95 per cent occurs at a deposit of DDT equivalent to that used in the time-toxicity study presented in figure 4. It has been mentioned in the section of correlation of laboratory and field data that an average newly hatched larva will take a little over 7 minutes to traverse the distance between the egg and the tip of the peach twig. On this basis, it may be seen that contact action alone is sufficient to cause the death of the larvae when exposed to the DDT deposit. The results of the test presented in figure 8 are somewhat lower than one might expect from an examination of figure 4. The differences between the two tests are as follows. The relative humidity has been raised 10 per cent in the apple tests. It does not seem to the writer that this difference in relative humidity is sufficient to cause the observed difference in toxicity. The second change is that larvae are allowed to remain on the apple surface until they either gain entry or die, whereas in the contact tests, larvae were removed after the desired time interval of exposure had elapsed. One might expect that this second change in conditions would result in a higher mortality in the apple tests, rather than the lower mortality actually observed in the test. The answer to the question probably lies in the different test surfaces used. In other words, the deposit is probably of a different nature on a glass slide than it is on a waxy apple surface. Conclusions.—The development of a laboratory method for determining the contact action of DDT is described.

Data are presented to show that a smooth surfaced preparation of pure, crystalline DDT (melting point 107–108°C.) is less toxic by contact action to newly hatched oriental fruit moth larvae than a similar preparation of DDT with a rough surface. Evidence is adduced to substantiate the theory that the observed increase in mortality is due primarily to the greater frequency of crystal contact with parts of the larva other than the walking surfaces while crawling over the rough surfaced preparation.

A DDT-benzene solution emulsified in water with B1956 showed negligible contact toxicity in comparison with wettable powder and dust formulations of DDT.

Data are presented to show that a period of 3 minutes and 45 seconds of contact with a deposit of DDT formulated as a wettable powder at a deposit of 1.89 micrograms of DDT per square centimeter results in 50 per cent mortality. Correlation of these data with observations on a field demonstration indicate that a close relationship exists between the two. Whether this relationship is reproduceable or not is unknown.

A comparison between the contact toxicity of a 50 per cent wettable powder and a 3 per cent dust formulation of DDT reveals that the toxicity curves cross at a point near the 50 per cent level of mortality, indicating that the actual toxicity level is essentially similar for the two formulations, but that the dust formulation acts more rapidly on the larva giving a higher kill at a shorter period of contact.

Reducing the temperature by 15°F., other factors remaining constant, resulted in an increase in mortality.

Evidence derived from tests in which the interaction of contact and ingestion toxicity of DDT was evaluated indicates that contact action alone is sufficient to account for the mortality observed in a population of newly hatched oriental fruit moth larvae when exposed to a 3-per cent DDT dust.

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Insecticide Tests for Boll Weevil Control During 1948[1]

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Experiments conducted near College Station in 1946 (Gaines & Dean, 1947) showed that a 3-per cent gamma benzene hexachloride–5-per cent DDT–40-per cent sulphur mixture was effective against most of the cotton insect pests. Additional tests conducted in 1947 (Gaines & Dean 1948) showed that the above mixture and 20 per cent chlorinated camphene–40-per cent sulphur were equally effective against the major cotton insects. These organic insecticides were more effective against the bollworm than was calcium arsenate, however, calcium arsenate was as effective as the organic sulphur mixtures when used against the boll weevil. In 1948, the new materials were recommended to the cotton planters of this state for the control of the major pests. The materials were widely used and reports indicated that they gave satisfactory control when properly applied. It has been estimated that over 5 million pounds of 20-per cent chlorinated camphene-sulphur and 7 million pounds of 3-per cent gamma benzene hexachloride–5-per cent DDT–sulphur were used in Texas during the season as compared to less than 2 million pounds of calcium arsenate. Planters used the new materials in an effort to obtain better control of the bollworm and to eliminate the aphid problem which often follows excessive applications of calcium arsenate. These materials also offered a possible control of all cotton pests, with one insecticide or insecticidal mixture.

The field tests herein reported, conducted in the Brazos river bottoms near College Station during 1948, were designed to compare several organic insecticides with calcium arsenate for control of the boll weevil, *Anthonomus grandis* Boh., and the bollworm *Heliothis armigera* (Hbn.). Infestations of bollworm did not develop to injurious numbers. Dust applications were made in the early morning with rotary hand guns, with the exception that an airplane was used on the large scale demonstration. Infestation records were made in the usual manner at 5-day intervals. The percentages of boll weevil infestation were transformed to equivalent angles for analyses of variance.

FIELD PLATS AND TREATMENTS.—Experiment 1, as shown in table 1, was conducted to determine the effectiveness of the following 5 materials when used against the boll weevil: (1) 20 per cent toxaphene–40 per cent sulphur, (2) 20 per cent toxaphene–0.5 per cent parathion, (3) 3 per cent gamma benzene hexachloride–5 per cent DDT–40 per cent sulphur, (4) 10 per cent chlordan–5 per cent DDT–40 per cent sulphur, and (6) special calcium arsenate (lime free)–1 per cent gamma benzene hexachloride. The plats were arranged in a latin square, each plat being 14 rows wide and of sufficient length to make one-seventh acre. Each treatment was replicated 6 times and each row and column contained an untreated or check plat. Six effective applications of all insecticides were made at approximately 5-day intervals from July 8 to August 3 at the rate of 12 pounds per acre.

Experiment 2, as shown in table 2, was conducted to determine the effectiveness of the following 3 materials when used against the boll weevil: (1) 20 per cent toxaphene–40 per cent sulphur, (2) 3 per cent chlordan–3 per cent DDT-inert and (3) special calcium arsenate (lime free)–1 per cent parathion. The plats were ar-

[1] Technical contribution No. 1179 Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

Table 1.—The boll weevil infestation, bollworm injury and yield of seed cotton on experiment 1 at College Station, Texas.

Treatment	Average Boll Weevil Infestation		Average Bollworm Eggs Number[2]	Average Bollworm Injured Bolls Per Cent[3]	Seed Cotton		
	Per cent[1]	Angles			Per Plat, Pounds	Per Acre, Pounds	Gain Over Check, Pounds
Special calcium arsenate plus 1% gamma benzene hexachloride	17.6	24.8	22.0	1.5	81.9	1638	430
Toxaphene sulphur (20% c. camphene)	23.7	29.1	22.4	.9	80.4	1608	400
Toxaphene parathion (20% c. camphene—.5% parathion)	26.7	31.1	20.5	1.5	83.7	1674	466
Gamma BHC-DDT-sulphur (3% gamma isomer-5% DDT)	33.1	35.1	25.3	1.1	75.8	1516	308
Chlordan-DDT-sulphur (10% chlordan-5% DDT)	43.0	41.0	16.8	1.6	81.7	1634	426
Check	59.2		9.6	4.3	60.4	1208	
Minimum significant difference at 5% level		4.9			7.8		

[1] Average of 6 records made from July 12 to August 4.
[2] Average of 2 records made from July 16 to July 21.
[3] Average of 5 records made from July 21 to August 9.

ranged in a latin square, each plat being 12 rows wide and of sufficient length to make one-tenth acre. Each treatment was replicated 4 times and each row and column contained an untreated check plat. Six effective applications were made at 5-day intervals from July 9 to August 3 at an average rate of 12 pounds per acre.

RESULTS.—The first bollworm eggs were noted early in July, the number reaching a peak by July 16. Records indicate that more eggs were found on the treated plats than on the untreated plats, possibly due to the destructiveness of these materials against the natural enemies. Bollworm injury was negligible, even on the untreated plats, probably due to the excessively dry, hot weather which existed at this time. It was assumed that the unfavorable weather either prevented the eggs from hatching or the young worms from surviving.

The seasonal averages of the different criteria for both experiments are shown in tabular form and the seasonal infestation data on experiment No. 1 are shown in figure 1.

In experiment No. 1, special calcium arsenate plus 1 per cent parathion and 20 per cent toxaphene-sulphur were equally effective against the boll weevil and both gave significantly better control than either 3 per cent gamma benzene hexachloride–5 per cent DDT-sulphur or- 10 per cent chlordan–5 per cent DDT–sulphur. The 20 per cent chlorinated camphene–40 per cent sulphur and 20 per cent chlorinated camphene–0.5 per cent parathion were equally effective. All the insecticides increased the yield significantly.

Results of cage tests conducted in both the field and laboratory (Gaines & Dean 1949) show that the high temperatures recorded during July and August affected the toxicity of some of these materials. The toxaphene compared favorably with calcium arsenate. In the field, benzene

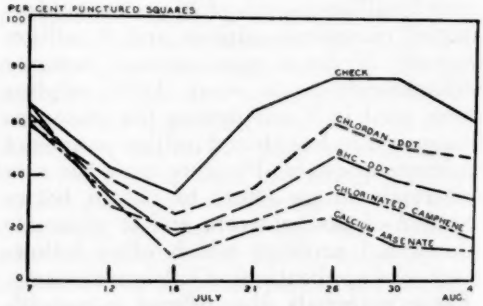

FIG. 1.—The average percentage punctured squares on plats receiving treatments as indicated in experiment 1, College Station, Texas.

hexachloride was effective for a period of 24 to 36 hours, but under the conditions of a heavy weevil migration it failed to prevent injury when the material was applied at 5-day intervals. The chlordan also failed to prevent weevil injury under

Table 2.—The boll weevil infestation, bollworm injury and yield of seed cotton on experiment 2 at College Station, Texas.

TREATMENT	AVERAGE BOLL WEEVIL INFESTATION		AVERAGE BOLLWORM EGGS NUMBER[2]	AVERAGE BOLLWORM INJURED BOLLS PER CENT[3]	SEED COTTON		
	Per Cent[1]	Angles			Per Plat, Pounds	Per Acre, Pounds	Gain Over Check, Pounds
Calcium arsenate plus 1% parathion	13.1	21.2	15.1	2.5	77.8	1945	403
Toxaphene Sulphur (20% c. camphene)	14.7	22.5	18.5	2.0	76.5	1912	370
Chlordan-DDT inert (3% chlordan-3% DDT)	35.8	36.8	8.5	2.7	72.5	1812	270
Check	42.6	40.7	5.1	4.2	61.7	1542	
Minimum significant difference at 5% level		7.7			8.8		

[1] Average of 6 records made from July 13 to August 4.
[2] Average of 2 records made from July 17 to July 22.
[3] Average of 5 records made from July 22 to August 9.

these conditions. Deficient moisture caused the late bolls to shed on all plats, thus preventing an increased yield in the plats where the best control was obtained.

In experiment No. 2, special calcium arsenate plus 1 per cent gamma and 20 per cent toxaphene-sulphur were equally effective against the boll weevil and both gave significantly better control than did the 3 per cent chlordan–3 per cent DDT mixture. All the insecticides increased the yield significantly. Deficient moisture also caused the late bolls to shed in this experiment, thus preventing an even greater difference in the yields of the treatments. The bolls that were protected from weevil injury by the more toxic materials failed to produce cotton.

A large scale demonstration was conducted in which airplanes were used to apply 4 materials (1) calcium arsenate, (2) 20 per cent toxaphene sulphur, (3) 3 per cent gamma benzene hexachloride–5 per cent DDT-sulphur and (4) 10 per cent chlordan–5 per cent DDT-sulphur. The results were the same in the demonstration containing large plats (25 to 40 acres) as shown for the replicated experiment containing smaller plats. Three of these large plats adjacent to pastures which had been dusted in May with 10 per cent toxaphene-sulphur for grasshopper control developed injurious infestations of red spider mites. This condition made it necessary to apply sulphur for the control of this pest late in June before any applications had been made.

A comparison is shown, table 3, of the increased yields over the check plats in comparable experiments conducted at this station for the control of the weevil and bollworm during the past 3 years. The organic insecticides, toxaphene or benzene hexachloride–DDT, are equally effective against the boll weevil, while the organic compounds are more effective against the bollworm.

Table 3.—Summary of increased yields in comparable experiments conducted for the control of the weevil and bollworm during three years at College Station, Texas.

YEAR	REPLICATES	GAIN OVER CHECK, POUNDS SEED COTTON		
		Calcium Arsenate[1]	3% Gamma Benzene Hexachloride-5% DDT-40% Sulphur	20% Toxaphene 40% Sulphur
1946	6	646	711	
1946	4	645	587	
1947	4	496	500	472
1947	6	247[2]	621	556
1947	4	204[2]	411	390
1948	6	430	308	400
1948	4	403		370
Ave.		439	523	438

[1] An aphicide was used when necessary.
[2] Reduced yields due to heavy bollworm damage, in other experiments the weevil was the most injurious pest.

SUMMARY.—Special calcium arsenate (lime free) mixed with either parathion or benzene hexachloride and 20 per cent toxaphene-sulphur were equally effective against the boll weevil. These materials were more effective than either the benzene hexachloride-DDT-sulphur or chlordan–DDT-sulphur under the conditions of a hot season and heavy migration.

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Relation of Chemical Constitution of a Series of Esters of Picolinic Acid to Toxicity as Insecticides[1]

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In the search for new organic insecticides, many N-heretocyclic compounds have been investigated, including pyridine and the picolines. For some time the workers in this laboratory have been interested in this group of compounds and have conducted considerable insecticidal research on them. King & Frear (1943, 1944, 1944a) and King *et al.* (1944b) made studies using 2- and 4-alkyl pyridines among other N-heterocyclics.

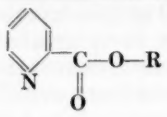
Of the pyridine carboxylic acids, the activity of nicotinic acid as a nutritive factor is well known. Its isomer, picolinic acid does not show this activity, which is further evidence of the correlation between chemical structure and biological activity. Picolinic acid has been shown to exert a fungistatic property in retarding the growth of molds (Hoffman *et al.*, 1942), but shows no activity as a contact insecticide or ovicide (LoCicero).[2] Recent studies have been made using picolinic acid to inhibit the catalyzed thermal decomposition of DDT (Gunther *et al.*, 1946, 1947, 1948). If a derivative could be found which would possess insecticidal properties, the compound might have considerable practical use.

There is no report of any biological tests of picolinic acid esters. LoCicero (1948) tested methyl 4-chloropicolinate, methyl 3, 5-dichloropicolinate, and methyl 3, 4, 5-trichloropicolinate as contact poisons and ovicides. As the per cent chlorine decreased, the insecticidal value increased. In view of these results, the present investigation was proposed. Its purpose was to measure the relative toxicity of a series of esters of picolinic acid as contact poisons and as ovicides.

PROCEDURE.—Preparation of materials. The methyl, ethyl, butyl, hexyl, octyl, decyl, dodecyl, tetradecyl, cetyl, and octadecyl esters were prepared according to a method described by Engler (1894). This consisted of refluxing picolinic acid hydrochloride and an excess of the desired alcohol under passage of dry HCl. The reaction mixture was made alkaline, and the excess alcohol and ester were distilled. The esters and some of their physical constants are listed in table 1.

Biological evaluation—aphids. To evaluate the above compounds as contact insecticides, aphids, *Aphis rumicis*, were used. A nasturtium plant heavily infested with approximately 200 aphids was placed on a small turntable which was enclosed in a wooden spray chamber equipped with an exhaust fan. The test solution or suspension, one per cent in 80 per cent acetone, was sprayed with an

Table 1.—Physical constants of the picolinic acid esters.



—R GROUP	B.p.	M.p.	n_D^{20}
$-CH_3$	$90^{2.0}$		1.4911
$-C_3H_5$	$98^{3.6}$		1.4928
$-C_4H_9$	$100^{1.0}$		1.4925
$-C_6H_{13}$	$118^{0.5}$		1.4920
$-C_8H_{17}$	$129^{1.4}$		1.4442
$-C_{10}H_{21}$	$140^{0.2}$		1.4542
$-C_{12}H_{25}$		50– 51	
$-C_{14}H_{29}$		46	
$-C_{16}H_{33}$		54	
$-C_{18}H_{37}$		109–111	

[1] Authorized for publication on July 15, 1949 as Paper No. 1529 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

[2] Unpublished thesis, 1948.

Table 2.—Toxicity of esters of picolinic acid (1 per cent in 80 per cent acetone) to aphids and nasturtium plants.

Compound	Per Cent Kill	PI[1]
Picolinic acid	67.9	S
Picolinic acid, methyl ester	35.8	N
Picolinic acid, ethyl ester	42.7	S
Picolinic acid, butyl ester	84.6	H
Picolinic acid, hexyl ester	93.5	H
Picolinic acid, octyl ester	38.5	S
Picolinic acid, decyl ester	33.9	N
Picolinic acid, dodecyl ester	33.3	H
Picolinic acid, tetradecyl ester	14.2	N
Picolinic acid, cetyl ester	0	N
Picolinic acid, octadecyl ester	0	N
Picolinic acid, 4-chloro-, methyl ester[2]	63.6	MH
Picolinic acid, 3,5-dichloro-, methyl ester[2]	34.5	N
Picolinic acid, 3,4,5-trichloro-, methyl ester[2]	27.6	N

[1] PI represents plant injury: N = none; S = slight; M = medium; H = severe.
[2] Prepared and tested by LoCicero. (Unpublished thesis, 1948)

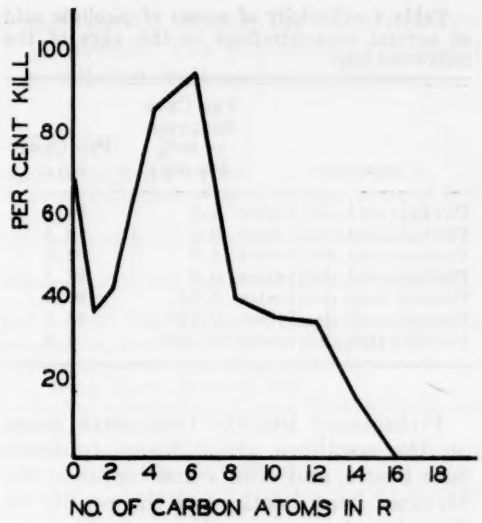


FIG. 1.—Toxicity of a 1 per cent solution of the esters of picolinic acid to aphids as related to the chain length of alcohol R.

atomizer-type spray gun at a pressure of ten p.s.i. and about 30 inches from the plant. The turntable rotated during the spraying. The sprayed plants were placed in the centers of sheets of paper, the edges of which had been smeared with Tree Tanglefoot to prevent the escape of surviving aphids. Twenty-four hours after spraying, the aphids, both dead and alive, were counted. Each compound was tested at least twice.

Milkweed bug eggs. To test the compounds as ovicides, large milkweed bug, *Oncopeltus fasciatus*, eggs were used. One hundred or more eggs, less than 24 hours old, were placed in a small test tube containing a one per cent solution or suspension in 80 per cent acetone. After 30 seconds immersion, these were filtered with suction and the filter paper and eggs were transferred to petri dishes. These were left uncovered for 24 hours to allow the escape of volatile matter. The eggs were counted and then left for 2 weeks to hatch. At the end of this time, the unhatched eggs were counted.

Table 3.—Toxicity of esters of picolinic acid (1 per cent in 80 per cent acetone) to eggs of the milkweed bug.

Compound	Per Cent Kill
Picolinic acid	3.7
Picolinic acid, methyl ester	9.5
Picolinic acid, ethyl ester	6.2
Picolinic acid, butyl ester	4.0
Picolinic acid, hexyl ester	1.9
Picolinic acid, octyl ester	90.4
Picolinic acid, decyl ester	96.6
Picolinic acid, dodecyl ester	22.0
Picolinic acid, tetradecyl ester	17.1
Picolinic acid, cetyl ester	42.4
Picolinic acid, octadecyl ester	10.6
Picolinic acid, 4-chloro-, methyl ester[1]	37.2
Picolinic acid, 3,5-dichloro-, methyl ester[1]	27.1
Picolinic acid, 3,4,5-trichloro-, methyl ester[1]	0.6

[1] Prepared and tested by LoCicero (1947, 1948). (Unpublished thesis.)

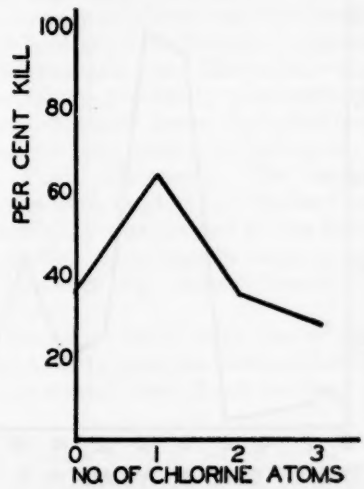


FIG. 2.—Toxicity of a 1 per cent solution of methyl esters of chloropicolinic acids to aphids as related to the number of chlorine atoms on the ring.

Table 4.—Toxicity of esters of picolinic acid at several concentrations to the eggs of the milkweed bug.

Compound	Per Cent Solution in 80% Acetone	Per Cent Kill
Picolinic acid, octyl ester	1.0	90.4
Picolinic acid, octyl ester	0.5	3.5
Picolinic acid, decyl ester	1.0	96.6
Picolinic acid, decyl ester	0.5	97.1
Picolinic acid, decyl ester	0.25	92.3
Picolinic acid, decyl ester	0.125	23.1
Picolinic acid, decyl ester	0.0625	1.8

Preliminary toxicity tests were made on the southern army worm, confused flour beetle, and adults and larvae of the Mexican bean beetle, but the results on these insects were negative.

Discussion.—In the aphid test, the esters showed varying degrees of toxicity with the greatest effectiveness in the butyl and hexyl esters as shown in figure 1. These esters were tested further using a 0.5 per cent solution, but this was ineffective. The phytotoxicity generally paralleled the insecticidal power.

As ovicides, the esters also showed varying degrees of toxicity, the results of which gave the same type of curve (Fig. 3) as that in the aphid test. However, the peak toxicity moved to the right indicating the octyl and decyl esters to be most effective. Further tests showed the octyl picolinate to be ineffective below the one per cent level. The decyl ester, however, was effective as low as one-fourth per cent concentration.

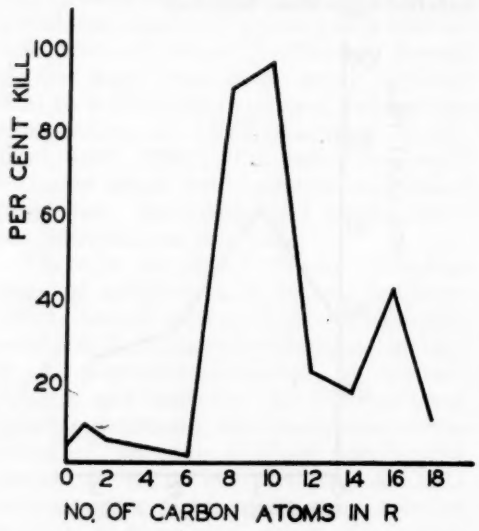


Fig. 3.—Toxicity of a 1 per cent solution of esters of picolinic acid to milkweed bug eggs as related to the chain length of alcohol R.

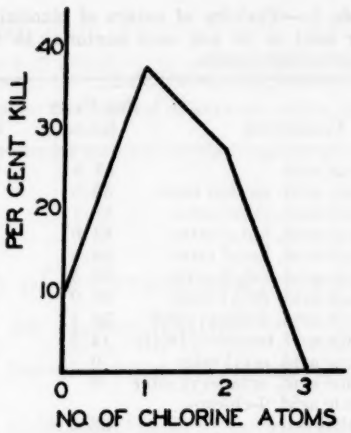


Fig. 4.—Toxicity of a 1 per cent solution of methyl esters of chloropicolinic acids to milkweed bug eggs as related to the number of chlorine atoms on the ring.

The results of methyl picolinate obtained from the aphid and ovicide tests were plotted (Figs. 2 and 4) with those obtained by LoCicero[2] using methyl esters of chloropicolinic acids. The per cent mortality was plotted against the number of chlorine atoms on the ring. In both cases, the peak toxicity was with the monochloro ester.

King & Frear (1944) showed that as a fumigant 2-butyl pyridine was more effective than other alkyl pyridines. LoCicero (1947) showed that the C_6 through C_{12} quaternary 4-(5-nonyl)-and 4-(n-amyl)-pyridinium chlorides were the most toxic of a series of alkyl substituted quaternaries. In the reported study, the peak over all toxicity was shown in the C_4 through C_{10} esters. Perhaps with alkyl substitutions in pyridine or other N-heterocyclics, the indicated range of carbon atoms is most desirable for insecticidal purposes.

Summary.—The methyl, ethyl, butyl, hexyl, octyl, decyl, dodecyl, tetradecyl, cetyl, and octadecyl esters of picolinic acid were prepared and tested as contact insecticides on aphids, *Aphis rumicis*, and as ovicides on large milkweed bug, *Oncopeltus fasciatus*, eggs. Maximum toxicity appears to lie within the range C_4

through C_{10} of the ester chain length as shown by tests using a 1 per cent solution. The C_6 ester was most toxic in the aphid test; the C_{10} showed the peak toxicity as an ovicide. The phytotoxicity generally parallelled the insecticidal efficiency.

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Chemical Treatment of Seed Corn for Control of *Agonoderus comma*[1]

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Agonoderus comma (Fabr.) is a small brown and black carabid, often confused with *A. lecontei* Chaud., the seed-corn beetle. Although *A. lecontei* is found in Minnesota and other northern states, *A. comma* is by far the more abundant species. They have similar habits although very few references in literature mention any economic significance attached to the latter.

The author found that *Agonoderus comma* adults will readily attack normal sound corn seed resting on the ground or planted beneath the soil surface. A closely related species, *A. lineola* (Fabr.) was also found to damage corn seed, but this species is relatively scarce in Minnesota.

The *Agonoderus comma* adult eats its way into the kernel, attacking the endosperm and germ. If the germ is attacked, germination is inhibited or stopped. The injury to seeds may also permit disease organisms to gain entry. Although damaged seeds will often grow, they usually produce weak sprouts. In cold wet springs when corn is slow to germinate, these insects are most likely to be detrimental.

The larval forms of *Agonoderus comma* and *A. lineola* are carnivorous; only the adults attack corn. *A. comma* adults also attacked other planted grain seed such as oats, barley, and wheat in the laboratory. Because of the great abundance of *A. comma*, and its potential hazard to planted corn, an attempt was made to learn some simple method of protecting corn seed against this beetle. Several insecticides were used as possible control materials in the tests, which were made in conjunction with biological studies of *A. comma*.[3]

MATERIALS AND METHODS.—As these insects are positively phototropic, most were obtained from an unbaited light trap, without poison, at University Farm, St. Paul, Minnesota. The number of beetles used was less than desired but their availability was limited at the time these particular experiments were made. All beetles were kept in jars of moist soil until needed.

One-ounce metal salve tins or pill boxes were used to hold the beetles during most of the actual tests. Each box had a piece

[1] Paper No. 2458 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

[2] The data contained herein are a portion of the results of research to be presented in the master's thesis as partial fulfillment of the requirements for the M.S. degree in entomology at the University of Minnesota. The author is indebted to Dr. A. A. Granovsky, Professor of Entomology, University of Minnesota, for suggestions and help during the actual research, and preparation of this paper.

[3] To be published elsewhere.

Table 1.—Control of *Agonoderus comma* by insecticides dusted on soil surfaces.

Soil Surface Treatments	Hours Between Treatment and Examination of Beetles						Dead After 120 Mos.
	1	2	15	41	67	120	
Benzene hexachloride 0.5 per cent gamma isomer	9M	9M	6M, 3D	4M, 5D	9D	—	100%
Chlordan 5 per cent	2N, 7M	9M	9M	9M	5M, 4D	9D	100
DDT 5 per cent	9N	9N	9N	6N, 3M	5N, 3M 1D	2M, 7D	78
Parathion 1 per cent	9M	9M	9M	9M	5M, 4D	9D	100
Pyrophyllite treated check	9N	9N	9N	9N	9N	9N	0

N = normal, M = moribund, D = dead.

of damp blotter on the bottom, covered with a thin layer of sifted moist soil. The lid of each tin was perforated with a slot, approximately 0.4 inch by 0.06 inch, to allow the free passage of air into the box and for the escape of any insecticidal fumes.

The corn seed was obtained from a 1947 open-pollinated field of Kingscrost G7, an eight-row hybrid sweet corn. Germination was tested in a greenhouse during June, 1948, when the rest of the experiments were made.

The following insecticidal dusts were used:

1. Benzene hexachloride, 0.5 per cent gamma isomer.[4]
2. Chlordan, 5 per cent.[5]
3. Toxaphene, 5 per cent.[6]
4. DDT, 5 per cent.[7]
5. Parathion, 1 per cent.[8]
6. Check, pyrophyllite, 100 per cent.

The toxaphene was obtained too late to be included in any of the tests, except for one soil dusting treatment. However, the other five materials, including the pyrophyllite check, were used uniformly in all experiments.

Dusted Soil.—The soil in each of 18 salve tins, using three replicates for each of the six materials, was lightly dusted by hand dusters, so as to deposit a very thin layer of insecticide on the soil surface. Three beetles were then introduced into each salve tin, giving a total of nine beetles for each treatment. It was necessary to test the toxaphene at a later date, and therefore the results are not entirely comparable, although performed under similar conditions. Results obtained with toxaphene are not included in table 1, but are discussed separately below.

Data for the other five materials are in table 1. The three salve tins of each set are grouped together for simplicity and total results only are presented. The beetles were examined periodically and the data showing a trend are listed. This is applicable to all tables included in this paper. The term moribund was applied to all beetles partially paralyzed, as well as those on their backs, feebly moving their appendages.

Of the five materials tested simultaneously, benzene hexachloride and parathion seemed to act most quickly. Chlordan was also very effective, but DDT was much slower to take effect. The check material, pyrophyllite, was not detrimental to the beetles.

Toxaphene, tested afterwards, did not affect beetles within the first hour, but after 4 hours, seven of the nine beetles were moribund. Movements of the other two beetles were uncoordinated. After 18 hours, one of the nine beetles was dead, and the other eight were moribund. After 42 hours, at which time this test was terminated, six were dead, and the remaining three beetles were moribund.

In this test, all beetles were in constant contact with the insecticide. Some of the materials give off fumes, and although the salve tins were ventilated, the fumigant action of certain materials could have added to the contact effect of the toxicants. An additional test which would be of value is one in which the beetles would be allowed to run over the dusted soil for a limited time, and then be removed to clean containers. Because of the lack of beetles, such a test was not made.

In order to test the effectiveness of these

[4] Made by mixing Sixide technical benzene hexachloride, 10 per cent gamma, with pyrophyllite. Benzene hexachloride from Commercial Solvents Corporation.
[5] *Dowklor*. The Dow Chemical Company.
[6] *Toxaphene*. Hercules Powder Company.
[7] McConnon and Company.
[8] American Cyanamid Company.

Table 2.—Residual toxicity of insecticides 14 days after application to soil surfaces for *Agonoderus comma* control.

Soil Surface Treatments	Hours Elapsed Between Introduction of Beetles and Examination				Moribund After 22 Hours
	1	3	6	22	
Benzene hexachloride 0.5% gamma isomer	6N, 9M	15M	15M	15M	100%
Chlordan 5%	15N	15M	15M	15M	100
Chlorinated camphene 5%	15N	15N	5N, 10M	15M	100
DDT 5%	15N	10N, 5M	15M	15M	100
Parathion 1%	11N, 4M	3N, 12M	15M	15M	100
Pyrophyllite check	15N	15N	15N	15N	0

N = normal, M = moribund.

materials after a prolonged exposure to air, all salve tins with dusted soil were saved. The lids were removed and the soil was exposed to the air in the laboratory for 9 days. The start of this second test, therefore, was 14 days after the original dust application. In the case of toxaphene, the second test was started seven days after dusting. For that reason the chlorinated camphene results, which are included in Table 2, are not entirely comparable to the other data in this table.

The soil was remoistened by the addition of distilled water applied to the margin of the soil in all the tins, and five *Agonoderus comma* adults were introduced into each, for a total of 15 beetles per treatment. In addition, one *A. lineola* adult was placed in one box of each of the three box series. Because of the comparative scarcity of the latter, only six adults were available for the test. Therefore, the results on this insect are not conclusive but the *A. lineola* adults do show a reaction similar to that of *A. comma*.

All of the materials retained a great deal of their toxicity after the 2-week exposure to air (Table 2). Benzene hexachloride, chlordan, and parathion were the fastest acting materials, with chlorinated camphene and DDT somewhat slower. Again the pyrophyllite did not affect the beetles.

Agonoderus lineola adults were affected by all of the insecticides. Parathion paralyzed a beetle within one hour, and killed it within 22 hours. Benzene hexachloride caused a moribund condition after 3 hours, and the chlordan treatment paralyzed another in 3 hours with a moribund condition after six hours. Both toxaphene and DDT caused paralysis after 6 hours and a moribund condition after 22 hours. *A. lineola* was not harmed by the pyrophyllite.

It was noted that all of the toxic materials caused both male *Agonoderus comma* and *A. lineola* to extrude their genitalia. The beetles remained in that condition even after death. A female *A. lineola* in

Table 3.—Results of exposing chemically treated corn seed to *Agonoderus comma* attack.

Seed Treatments	Hours Elapsed Between Treatment and Examination of Beetles							Percentage Dead After 216 Hours
	3	21	45	72	96	144	216	
Benzene hexachloride 0.5% gamma isomer	2N, 4M	3N, 3M	2N, 3M 1D	2N, 2M 2D	4N, 2D[1]	4N, 2D[2]	4N, 2D	33
Chlordan 5%	5N, 1M	5N, 1M	5M, 1D	5M, 1D	4M, 2D	6D	—	100
DDT 5%	6N	6N[2]	6N	6N	6N[2]	6N[3]	6N	0
Parathion 1%	6N	6M	1N, 5M	1N, 5M	2N, 2M[1] 2D	2N, 4D	2N, 4D	67
Pyrophyllite treated check	6N	6N[3]	6N	6N	6N	6N	6N	0

N = normal, M = moribund, D = dead.
[1] One corn seed partially eaten.
[2] Two corn seeds partially eaten.
[3] Three corn seeds partially eaten.

the benzene hexachloride treatment laid one egg after paralysis had occurred. The egg proved to be non-viable.

CORN SEED TREATMENT.—The sweet corn seed was divided into five equal lots, and each was treated with a different material. Toxaphene was not available for any of the following experiments, but the five other materials were tested. A small amount of the dust was shaken up with the corn in a closed container, and excess dust was removed by vigorous agitation of the corn in a seive. Approximately 2 to 3 ounces of dust were required per bushel of corn.

Two *Agonoderus comma* adults were placed in each of 15 salve tins, thereby allowing three replicates and six beetles for each treatment. One treated kernel was placed in each tin.

Table 3 shows the results of corn seed treatment. The pyrophyllite treated corn was attacked by the beetles within 21 hours after the dry kernels were introduced. The DDT treatment was comparatively inefficient, as one of the three kernels was attacked within the first 21 hours. Even after 9 days the DDT treatment seemed to have little or no effect on the beetles. All DDT treated kernels were as badly damaged as the check and the beetles appeared to be healthy.

Chlordan was the most effective material used in this experiment. It was the only insecticide which completely protected the seed, and which killed all six beetles. Parathion was fairly toxic, but two moribund beetles apparently recovered, and later attacked one kernel of corn. The other four beetles died. Benzene hexachloride proved to be of value also, but some beetles apparently recovered from the toxic effects, and two kernels were damaged.

In another experiment the treated seed was planted in 5-inch pots of soil in the greenhouse. Five kernels of corn were used per pot, planted at a depth of 1 inch in the soil, under a gauze-covered lamp chimney. Three replicate pots were used for each of the five materials. Six hours after planting, seven adult beetles were introduced into each pot, giving 21 beetles and 15 kernels of corn per treatment.

The pots were not disturbed for 14 days, except for occasional watering. By this time the corn was well sprouted, but few or no differences could be noted in the size or appearance of the sprouts, all plants being fairly vigorous. The soil was then removed from the pots and examined for beetles. The sprouted kernels were also inspected for damage.

Certain factors made evaluation difficult. The kernels of corn which had been in the soil for 14 days had been sprouted for 10 days, and were difficult to examine. In some cases it was a problem to decide whether damage was due to beetle attack, breaking of the seed coat by the emerging sprout and root, decay, or tearing of the seed in removal of the plant from the soil. However, an attempt was made to list only those attacked by the insect as damaged (Table 4).

Table 4.—Results of planting chemically treated corn seed in greenhouse soil and exposing it to *Agonoderus comma* attack. Corn examined nine days after planting.

Seed Treatment	Sprouted Kernels[1]		Beetles in Soil[2]	
	Normal	Damaged	Normal	Affected
Benzene hexachloride 0.5% gamma isomer	9	40	7	1 dead
Chlordan 5%	11	27	4	4 dead 1 moribund
DDT 5%	5	67	9	0
Parathion 1%	11	27	9	0
Pyrophyllite treated check	7	53	10	0

[1] Fifteen kernels planted.
[2] Originally introduced 21 beetles.

Another difficulty was the recovery of the insects from the soil. A number of the beetles escaped because they tunnel freely through the soil, and there was nothing to prevent them from going under the lamp chimney, which was imbedded in the soil approximately an inch. A few may have dug deeply enough to escape through the hole in the bottom of the pot. As may be noted in table 4, out of the original 21 beetles per treatment, 8 to 10 remained per treatment at the end of the experiment. Although germination was rapid, there were still enough beetles present to injure the corn severely.

Chlordan and parathion afforded the most effective protection (Table 4). The chlordan treatment affected the greatest number of beetles, and permitted only 27 per cent damage to the corn. Parathion resulted in the same percentage of damaged kernels, but no affected beetles were found, although nine living beetles were still present. It is possible that

parathion has a repellent effect on this species.

Kernels treated with benzene hexachloride sustained slightly more damage and only one dead beetle was found. Perhaps benzene hexachloride also repels *A. comma*. The DDT and pyrophyllite treated kernels were very severely injured. No affected beetles were found in either of these treatments. One of the injured kernels and accompanying plant in a DDT treated replicate was rotted, but individual kernels in the check pots were the most badly damaged.

As a final test, to learn what effect these chemicals might have on the germination of the corn, 500 kernels, 100 for each of five materials, were treated and planted immediately in flats of soil. These were kept in a greenhouse and observed daily. No ill effects could be observed for any of the materials. Seeds for all treatments germinated well, shoots appearing above the soil on the fifth day after planting. All plants appeared to be healthy and normal. At the end of the ninth day all plants were counted and examined. No abnormalities were noted.

The following germination percentages were obtained with the seed treatments listed: benzene hexachloride 98 per cent, chlordan 100 per cent, DDT 99 per cent, and pyrophyllite 100 per cent.

CONCLUSIONS.—Although no insecticide gave perfect control of *Agonoderus comma*, in these tests chlordan proved to be most consistently superior to other materials used. Parathion is also effective. but slightly less so than chlordan. Benzene hexachloride is somewhat effective but inferior to chlordan and parathion. Both parathion and benzene hexachloride may have repellent properties. Toxaphene was included in only one test but it may be of some control value. DDT is ineffective in the control of *A. comma*, and in most cases gave results comparable to the pyrophyllite treated check.

The compatibility between organic fungicides and these insecticides is only partially known. Arnason reports that mercury fungicides can be used with benzene hexachloride on cereals without serious effects. Hamner stated that mixtures of DDT and five fungicides were apparently compatible and did not affect germination of corn.

If the more effective materials used in these experiments are compatible with the commonly used organic fungicides, the easiest way to protect corn may be to merely coat the seed with a layer of insecticide-fungicide combination dust before planting. Although these tests have not been verified by field trials, insecticidal treatment of corn seed may permit cheap and safe protection against *Agonoderus comma*, related *Agonoderus* species, and possibly against certain other insects which attack corn seed after planting.

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DR. HUNGERFORD RETIRES

Dr. H. B. Hungerford has retired as head of the Department of Entomology of the University of Kansas and State Entomologist, southern division of Kansas. He will continue his teaching, both at the University of Kansas and, during summer months, at the University of Michigan Biological Station. He expects to continue his research program on the aquatic Hemiptera. Having recently published a revision of the Corixidae of the Western Hemisphere, he plans to complete his study of the Corixidae of the Eastern Hemisphere.

He is replaced as chairman of the Department of Entomology and State Entomologist by D. Charles D. Michener, who is continuing studies now in progress on the saturniid moths and plans to continue his principal research studies in the taxonomy, evolution, biology and behavior of bees.

Interrelation of Peach Insects and Disease Control at Orleans, Indiana[1]

G. Edw. Marshall, *Purdue University Agricultural Experiment Station*

One of the leading problems in peach production is brown rot. But few investigators or commercial growers understand how to step into an orchard wherein brown rot has taken much of the crop for several years and execute a production program which will result in commercial control in one year. By commercial control is meant a crop that is at least 85 per cent free from brown rot (including ripe drops) as the peaches are harvested and ready to go over the grading table. There are, of course, many things known about brown rot, all of which are an aid in holding the disease in check. Certain of these have to do with each of the several phases of production such as pruning, sanitation, control of insects, spraying, and fruit handling. Notwithstanding, our present knowledge is not sufficient to assure us that we can produce a commercially clean crop after brown rot and insects have once caused heavy losses to the crop in an orchard. So, good reasoning would suggest that any practicable means of preventing the initial incidence of disease and insect inroads is worth consideration. Furthermore, a "clean up" in one year as was attempted by many growers in 1948 is often disappointing. Using this logic this problem has been attacked at Orleans, Indiana. The work was done primarily as an aid to new growers who, from the beginning, can and will prevent initial heavy infection of brown rot and infestation by insect pests. Benefit may also be derived from the studies by growers who have experienced heavy brown rot losses, but who are willing to adopt new and better practices and methods as they become known.

An orchard of Gage Elberta was set in 1941. It has not missed a crop in 5 years. The planting is located on a sodded slope of 8 or 10 per cent grade. To prevent serious erosion the sod has not been disturbed except beneath the limb spread of the trees. In southern Indiana some similar method of culture must be used frequently for dozens of ridge or hilltop orchards must be left in sod if they continue in production. Hoeing when needed keeps the soil beneath the trees free of weeds and grass thus facilitating the removal of dropped fruit. This method of culture simplifies two of the four major phases of disease and insect control, and complicates two others for:

1. All drops are easy to see and since they are removed periodically the control of brown rot is simplified.
2. With the removal of all drops at regular intervals all the curculio and oriental fruit moth larvae are likewise removed. Thus the orchard-produced infestation of these two insects is held to a minimum.
3. Sod culture complicates the control of insects which cause catfaced peaches.
4. Sod culture makes conditions more favorable for the successful overwintering of the plum curculio.

In the execution of many sanitary measures in the orchard the labor cost is the big item. To gather information on this subject, keeping the soil free of weeds and grass beneath the trees and the constant removal of drops therefrom was made an important part of the operations contributing toward insect and disease free fruit. Cost data gathered during the season are as follows:

1. The peach crop from this block of peaches set in 1941 grossed $1013.00 per acre. The value of the peaches amounted to $14.33 per tree.
2. At 50 cents per hour for labor the cost of keeping the soil free of weeds and the drops picked up was 65 cents per tree.
3. This leaves $13.68 earned per tree.

In the opinion of the writer if the several points given consideration in curculio, oriental fruit moth and brown rot control were to be proven plot-wise, rather large plots would be necessary to prevent the exchange of insects and diseases from one plot to the other. Adequate space was not available for plantings to permit this type of study. Each item of merit in such a production program as the one discussed here may be difficult to prove as simply as may be done in plot comparisons. Furthermore, it may be

[1] This paper has been assigned Journal Paper No. 395 of the Purdue University Agricultural Experiment Station.

impossible to determine which single spray or orchard practice is the most helpful in holding diseases or insect pests to a negligible quantity. Yet, certain tangible evidences resulting from the methods used will be considered pertinent by anyone who understands peach production problems. Some of these are:

1. Not more than one spray or dust has ever been needed for brown rot.
2. Among others one commercial orchard less than a mile away had 100 per cent of the fruit destroyed, by brown rot three to five days after the hard ripe fruit was picked in 1948. This followed the application of more than the suggested number of sprays and dusts to control the disease.
3. The plum curculio caused less than 2 per cent loss of the crop though 5 per cent is common in the neighboring commercial plantings.
4. The oriental fruit moth caused less than 3 per cent loss though the neighboring crop has often been 33 per cent infested.
5. For several years, in the orchard under study, peaches which have dropped because they were dead ripe, dried up on the ground without rotting. Those left hanging on the trees often shrivel from loss of water without any decay.

Data has been presented by other workers showing the increase in brown rot infection accompanying injuries to the skin of peaches whether such injuries be from the curculio or oriental fruit moth or purposely made with pen or knife. Brown rot has long been known to thrive best under conditions of heavy insect attacks. In this study emphasis has been placed on holding the population of curculio and oriental fruit moth to a minimum. As this has been done brown rot has been a very minor problem, so minor in fact, that not as much consideration has been given it as has been given peach leaf curl control. While certain of the practices, used to hold insect infestation to a low level, have not been found desirable in large commercial plantings, they have served the purpose of demonstrating the points under consideration for they have kept the insect population down; brown rot has remained no threat, and the losses from the oriental fruit moth have remained very low. As a result we are safe in making the statement that if brown rot gains the upper hand in commercial production as it has in southern Indiana the problem is one of the grower's own making. Some of the methods used in holding insects in check are listed below:

1. For 3 years the oriental fruit moth was held to a low level by clipping off the infested twigs every 5 to 7 days during the greater part of the growing season. In addition, in going over the trees if any blemished peaches were seen these were removed.
2. In 1947 DDT was used against the fourth brood of the oriental fruit moth. The harvest infestation of the fruit from that insect was 2.5 per cent.
3. In 1948 DDT was used against the third brood of the oriental fruit moth. The insect attacked almost every twig during second brood. At harvest the infestation of this insect in the fruit was less than 1 per cent. Control accomplished in the third brood permits better twig growth than when it is directed against the fourth brood. In 1948 the twig growth after the DDT applications began was as much as 8 inches.
4. Lead arsenate has always been used to control the plum curculio. Control has been excellent each year, and in 1948 curculio infested fruit amounted to less than 1 per cent at harvest time.
5. The drops have always been picked up periodically.

Through the use of DDT the possibility of a mite infestation arises. Through the use of lead arsenate the probability of foliage injury presents itself. Neither has caused considerable damage in recent years. Both are annual problems in that they may develop from no importance to become serious in one year. Brown rot, on the other hand, takes more than 1 year to become a serious problem in production. It is probable that heavy mite infestations have not built up because the use of DDT has been purposely confined to a period of about a month in midsummer. When DDT is so used in apple production mites have not developed into serious populations—thus corroborating results from the peach work.

Another important phase in peach pro-

Table 1.—Spray schedule for Gage Elberta peaches harvested August 18 to September 1.

DATE	PLOT 1	PLOT 2	PLOT 3	PLOT 4
April 8	1 pt. chlordan[1]	1 pt. chlordan	1 pt. chlordan	1 pt. chlordan
April 23	.4 pt. chlordan	.4 pt. chlordan	.4 pt. chlordan	.4 pt. chlordan
May 1	.8 pt. chlordan	2 lbs. lead arsenate 4 lbs. zinc sulphate 6 lbs. lime	3 lbs. lead arsenate 16 lbs. lime	3 lbs. lead arsenate 16 lbs. lime
May 14		2 lbs. lead arsenate 4 lbs. zinc sulphate 6 lbs. lime	3 lbs. lead arsenate 16 lbs. lime	3 lbs. lead arsenate 4 lbs. zinc 16 lbs. lime
May 17	.8 pt. chlordan			
May 24	2 lbs. lead arsenate 4 lbs. zinc sulphate 6 lbs. lime	2 lbs. lead arsenate 4 lbs. zinc sulphate 6 lbs. lime		
June 1			16 lbs. lime	16 lbs. lime
June 10			16 lbs. lime	16 lbs. lime
July 7	12 oz. DDT[2] with 4 oz.[3] colloidal spreader (to entire orchard)			
July 10			16 lbs. lime	16 lbs. lime
July 13	12 oz. DDT with 4 oz. colloidal spreader (to entire orchard)			
July 20 & 21	12 oz. DDT with 4 oz. colloidal spreader (to entire orchard)			
July 27	12 oz. DDT with 4 oz. colloidal spreader (to entire orchard)			
Aug. 9	6 lbs. wettable sulphur (outside application only to entire orchard)			

[1] Actual—all amounts given for 100 gallons of spray.
[2] An inside-out and an outside-in application in first spray only.
[3] Colloidal Products Co. *Zl*.

duction is that of foliage injury. Bacterial spot, spray and dust applications, and poor nutrition have all been contributors toward heavy losses through foliage injury. Small plots are quite satisfactory in the study of these points, and have been used for this purpose.

It is probable that bacterial spot caused by *Bacterium pruni* did not exist in this Gage Elberta block this season, for never at the same time was there any perceptible attack of anything resulting in foliage injury over the entire orchard. On the contrary, injury which in many cases would have been identified as *B. pruni* did develop plot-wise, one plot at a time as follows:

Plot 1 —Developed foliage injury about May 20—never proved serious.

Plots 3 & 4—Developed foliage injury about June 8—looked better July 13.

Plot 2 —Developed foliage injury about July 19. Fruit injury developed July 18, heavy fall of leaves July 27.

Plots 7 & 8—Developed foliage injury July 31 to August 5 after first dust application (Table 2).

When lime, known to be fresh, has been used early enough and in sufficient quantities peach foliage has remained of the finest even though as many as four sprays of acid lead arsenate at 3 pounds per 100 gallons of water have been used to control the plum curculio. Table 1 of the heavy spray schedules of 1948 show the lead and lime dosages used in curculio control. Excellent foliage was maintained with the heaviest of these (Plot 3).

Zinc sulphate with a moderate amount of lime has long been considered satisfactory as a combination for maintaining good foliage yet the only serious foliage injury in the 1948 plots was in those in which zinc sulphate was used (plot 2, Table 1). From all the plots the only injured fruit resulted through the use of this lead-zinc lime combination. This was the combination suggested for use in the 1948 recommendations for Indiana. Observations of four dust schedules made it possible to single out the zinc as a contributing factor in the foliage injury. These dust schedules were as follows:

Table 2.—Dust treatments applied with a sticker.[1]

PLOT NUMBER	5	6	7	8
Sulphur	2.1 lbs.	2.1 lbs.	2.1 lbs.	1.98 lbs.
Lime	.3	.3	.15	.15
DDT (50%)	.3	.3	.3	.3
Lead arsenate	.3	.3	.3	.3
Sticker[1]	.0	.25	.0	.12
Zinc sulphate			.15	.15

[1] *Armours.*

Where the last two dust schedules of table 2 were applied foliage injury developed immediately after the first application. Comparing these four schedules it will be noted that the lime content is also lower in the last two, the only ones containing zinc sulphate. However, the spray schedule (table 1, plot 2) in which zinc sulphate was included contained what is considered an adequate amount of lime and here the lime was known to be freshly hydrated. Thus the indications are that the injury was caused by the zinc sulphate and not by low lime content.

The catfacing of peaches by Lygus and Pentatomid bugs of various species constitutes a study needing some attention. While the tarnished plant bug does not usually fly far at one time, stink bugs are strong of wing and may fly great distances. If catfacing was limited to the tarnished plant bug small plots would suffice.

From studies made to date it seems entirely possible that chlordan is controlling one species fairly well, but not the other. Table 3 gives the 1948 results of combinations of chlordan and lead arsenate in controlling the first brood of curculio, catfacing insects and the oriental fruit moth. Counts for these data were made at thinning time. From trees away from the outside of the block, limbs containing 100 peaches or more were tagged and the fruit thinned to 8 inches. Only perfect peaches were left, and the thinnings were saved and examined for insect attack. The crop from which these counts were taken was heavy. Had it been a light one the percentage of catfaced peaches would have been heavier accordingly. These results do show nevertheless, that catfacing was not excessive in this sod planting.

Table 3.—First brood infestation counts of Gage Elberta plots.

Treatment No.	All Treatments Applied Against First Brood Curculio and Plant Bugs: Materials Applied per 100 Gallons	Catfaced	Oriental Fruit Moth	Curculio
1	Chlordan 3 sprays; Lead Arsenate 2 lbs, zinc sulphate 4 lbs. lime 6 lbs.—one spray	5.7%	.01%	.025%
2	Chlordan 2 sprays; Lead Arsenate 3 lbs. lime 16 lbs.—three sprays	7.4	.05	.000

In these schedules the use of DDT is not only intimately tied up with residue, but with the mite problem, oriental fruit moth, and borer control as well. At harvest after four sprays put on between July 7 and July 27, 2.25 inch peaches carried a residue of 9.1 parts of DDT per million. The efficiency of the oriental fruit moth control may be seen in table 4 (less than 1 per cent of the fruit infested at harvest). To secure the counts given in this table two peaches were taken from each half-bushel of picked fruit as it came in from the orchards. These were spaced 4 inches apart on a shed floor to prevent the spread of brown rot from one peach to another. They were kept 3 or 4 days before slicing and examination to permit seeing very small larvae more easily.

Table 4.—1948 infestation counts of three commercial peach orchards in the vicinity of the test orchard.

No.	Date Picked	Date Sliced	Brown Rot	Oriental Fruit Moth	Curculio
1	Aug. 19	Aug. 20–24	100.0%	33.3%	5.1%
2	Aug. 19	Aug. 21–24	100.0	25.5	5.8
3	Aug. 20	Aug. 24	31.6	16.3	4.0
Test Orchard	Aug. 25	Aug. 26	12.2	less than 1 per cent	

It is not uncommon for growers to apply four or five sprays or dusts for brown rot control. In 1948 this was done in the commercial orchards listed in table 4 yet as may be seen, brown rot loss was still high. In comparing the three commercial orchards listed, the cost of three or four sprays or dusts, and the loss from brown rot both may be charged directly to the spray and dust control program, for only one sulphur-containing spray was applied to the test orchard under study; and yet in the latter brown rot control was the best.

The peach tree borer ordinarily demands considerable attention and labor for control. It has for the past 2 years been a very minor problem. In 1948 one spray of 3 pounds of DDT per 100 gallons was applied to the tree trunks on June 30. On July 7 the DDT applications against the third brood of the oriental fruit moth began. No other attention has been given the borer and none are to be found working in the tree trunks.

In 1948 the two-spotted spider mite began to cause considerable foliage injury

by August 25 in two places in the orchard. This occurred after four sprays of DDT, the applications made at 5 to 7 day intervals. However, a rain of 1.75 inches on August 29 checked the mite infestation for the remainder of the season. Here then is another indication that the use of DDT earlier in the season or over a longer period is almost certain to result in a spider mite problem. Had DDT been used early for catfacing insects no doubt a very serious mite infestaion would have occurred. Then it would have been necessary to apply an acaricide one or more times.

CONCLUSIONS.—All things considered, through this work and that of some other investigators, it would seem as though chlordan used for the Lygus insects which catface peaches, benzene hexachloride in the early part of the season or until about July 15, and DDT for the oriental fruit moth later, would be about as satisfactory a schedule as could be adopted. By eliminating lead arsenate from the schedule it may be possible to omit most of the applications of lime for preventing foliage injury.

Another approach to the problem may well be considered. If chlordan continues to give a good account of itself in the control of insects which catface peaches, it will at the same time control the curculio. This will eliminate most of the threat of foliage injury. Furthermore, in 1948 using DDT our efforts have been directed against a single brood, the third, of oriental fruit moth. The success attained in the control of the insect in the fruit and at the same time in the twigs, and without a serious mite infestation to combat, gives much promise that such a schedule will be a satisfactory one. One possible exception lies in the event the oriental fruit moth continues to increase in its attack on the peaches during the second brood, as it did in some orchards in Indiana in 1948. If this takes place, it may be necessary to apply control measures earlier than the third brood.

The Metabolism of DDT in the Large Milkweed Bug

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An understanding of the metabolic fate of an insecticide may be essential to the proper interpretation of its mode of action. This would be particularly true if it should happen that a metabolite rather than the insecticide itself is responsible for the poisoning effects observed. For many of our organic insecticides we lack analytical methods which are specific and sufficiently sensitive to justify a study of their metabolism in an insect. The development of a colorimetric method by Schechter *et al.* (1947) for the determination of DDT (1-trichloro-2,2-bis(p-chlorophenyl) ethane) and certain of its suspected metabolites made it appear feasible to use this compound and to study its fate in relation to the development of the chain of physiological events which appear in the poisoning process. The solution of the problem seemed all the more reasonable because work done on the metabolism of DDT in warm blooded animals pointed to certain compounds, namely 1-dichloro-2,2-bis(p-chlorophenyl) ethylene DDE and (2,2-bis(p-chlorophenyl) acetic acid DDA which were considered by White & Sweeny (1945) to be an intermediate and an end product respectively of DDT metabolism.

The large milkweed bug, *Oncopeltus fasciatus* (Dallas), was used to study the metabolism of DDT, primarily because it could be reared conveniently in large numbers. Since it was desired to study only that portion of the DDT dose which was exposed to the metabolizing mechanism of the insect, the compound was applied by injection through the cuticle. Thus it seemed reasonably certain that possible errors due to loss of dosage from physical means or failure of the compound to be absorbed through the cuticle, as might occur with topical applications, were minimized.

TOXICITY.—It seemed desirable to explore the metabolic fate of DDT through a range of dosages which would be limited by the maximum sublethal and slightly above lethal dosages for the insecticide.

As a consequence, a series of toxicity tests were made to establish these limits.

Pure p,p'isomer of DDT (m.p. 107–108° C.) was dissolved at the rate of 500 mg. in 10 ml. of a solution consisting of 8 parts peanut oil and 2 parts of sorbitol mono-oleate by volume. This solution readily formed a stable emulsion when diluted with distilled water, and as such was used for treating the insects in one series of tests. DDT was also used in acetone solution in another series of tests.

The insects used in these experiments were selected from groups of 5 to 10 day old male adults which varied in weight from 40 to 60 mg.

The insecticide was applied by means of a 27 gauge hypodermic needle attached to a 0.25 ml. tuberculin syringe fitted with a hand driven micrometer for advancing the plunger. The injection was made between the last thoracic and first abdominal segments on the ventral side of the insect. In making the injection, care was taken to insert the needle in such a way that when it was withdrawn, the cuticle fell back into place and sealed the puncture. In all cases the volume of injected solutions was kept constant at 2 cubic millimeters for the peanut oil emulsions and 1 cubic millimeter for the acetone solutions. The dosage was adjusted to the desired level by changing the concentration of DDT in the solvent.

The results of the toxicity studies are shown in table 1 where it will be noted that the LD-50 for DDT applied as a peanut oil emulsion is approximately 170 μg./g. It was observed that a period of 96 hours was required for the peanut oil emulsions of DDT to produce their maximum effects on the insects, whereas a 24-hour period seemed to be sufficient in the case of DDT-acetone solutions for the full effects of the treatments to be observed. These findings are in general agreement with those of Tobias *et al.* (1946) who observed that acetone-DDT solutions were more rapid in action and more effective than peanut oil emulsions applied in a similar manner to the American roach.

IDENTIFICATION AND EXTRACTION.—Calibration curves were prepared for the quantitative identification of DDT by both Schechter and ultraviolet spectrophotometric techniques. Similar cures were made for all other compounds used in this study that were susceptible to determination by the two methods. Other than DDT the compounds 1-dichloro-2,2-bis(p-chlorophenyl) ethylene, 2,2-bis(p-chlorophenyl) acetic acid, bis-(p-chlorophenyl) methane, 4,4'-dichlorobenzohydrol, 4'4-dichlorobenzophenone and p-chlorobenzoic acid were considered as being possible metabolic products of DDT and a scheme for their extraction and identification was devised. Each experiment made upon DDT or a suspected metabolite involved the use of 40 adult male milkweed bugs. The insects were injected with the desired dosage and subsequently macerated in the presence of anhydrous sodium sulfate, which aided in the grinding process, and at the same time, dehydrated the tissues and prevented the formation of emulsions during the extraction process. These macerated tissues were then treated with 25 ml. of chloroform and shaken intermittently during a 24-hour period. At the end of this time, the chloroform was decanted and the bug residues were shaken for a few minutes in a second 25 ml. quantity of chloroform. The chloroform was then filtered from the bug residues and added to the first chloroform extract. From the point the extract was treated in a manner similar to that described by Schechter *et al.* (1947) for the isolation and deter-

Table 1.—Toxicity of DDT applied subcutaneously to the adult male milkweed bug.

No. Bugs	Solvent	Per Cent Mortality[1]	Dosage DDT μg./gram Bug
20	Peanut Oil (emulsion)	0	41
50	"	10	102
10	"	20	130
20	"	30	145
50	"	50	171
20	"	70	182
20	"	80	220
40	"	100	265
40	"	0	—
20	Acetone	10	37
20	"	20	33
20	"	30	43
20	"	35	50
20	"	50	60
20	"	55	65
20	"	80	82
20	"	90	126
20	"	0	—

[1] The mortality for DDT-peanut oil emulsions was determined 96 hours after treatment, whereas in case of DDT-acetone solutions the mortality is that obtained after 24 hours.

mination of DDT in milk. This method is shown in the diagram, figure 1.

The scheme of extraction and analysis presented in figure 1 was successfully used to recover nearly theoretical quantities of the compounds previously enumerated. The reliability of the method was checked by injecting the compounds into milkweed bugs which had previously been killed by immersion for 3 minutes in boiling water, after which the bugs were subjected to the same systems of extraction and analysis. The only variation required in the extraction procedure outlined in figure 1 was in the number of acid washes necessary to remove fats from the chloroform extract. Concentrated sulfuric acid containing 5 per cent anhydrous sodium sulfate was added to the chloroform layer in 25 ml. portions and shaken vigorously. This process was repeated until both the acid and chloroform layers were nearly colorless after about 5 minutes of vigorous shaking. It was usually necessary to make three such treatments on each extract.

After the treatment as outlined in figure 1, the duplicate chloroform and alkaline aqueous extracts of chloroform extracts were analyzed in accordance

CHCl₃ extract of 40 bugs previously injected with DDT. The extract could possibly contain:
A. DDT B. DDE C. DDA
D. Bis(p-chlrophenyl) methane
E. 4,4'-dichlorobenzohydrol
F. 4,4'-dichlorobenzophenone
G. p-chlorobenzoic acid
H. CHCl₃ soluble bug products
I. Acid insoluble products of H
CHCl₃ washed with 2% NaOH
CHCl₃ containing A,B,D,E,F,I
NaOH layer containing sodium salts of C,G,H
H₂SO₄ washes
make acid to pH 2 with 6 N H₂SO₄
CHCl₃ containing A,B,C,D,E,F,I
Discard acid layer H
Extract with ether
CHCl₃ washed with 5% NaHCO₃
Discard NaHCO₃
CHCl₃ containing A,B,D,E,F,I
Ether containing C.G.H
Discard acid layer
Filter through cotton plug and evaporate CHCl₃
Ether dried with sat. NaCl solution
Ether removed
Residue contains A,B,D,E,F,I
Residue contains C,G,H
10 cc. ether added
10 cc. ether added
5 cc. aliquots of above solution transferred to 25 cc. flasks.
5 cc. aliquots of above solution transferred to 25 cc. flasks.
5 cc. ether containing A,B,D,E,F,I
5 cc. ether containing A,B,D,E,F,I
5 cc. ether containing C,G,H
5 cc. ether containing C,G,H
Ether removed and residue nitrated by the Schechter method
Ether removed and residue dissolved in cyclohexane for ultraviolet analysis
Ether removed and residue nitrated by the Schechter method
Ether removed and residue dissolved in methanol for ultraviolet analysis

FIG. 1

Table 2.—DDT recovered from bugs injected with 100 μg. DDT/g. DDT in a peanut oil emulsion.

Interval between injection and extraction	10 min.	25 min.	1 hr.	2 hr.	3 hr.	5 hr.	14 hr.	24 hr.	48 hr.
Gammas (μg.) of DDT recovered per gram bug	66	61	60	50	55	44	48	33	27

with the method described by Schechter *et al.* or were dissolved in either cyclohexane or methanol and subjected to ultraviolet spectroanalysis.

Experiments.—The preliminary studies of the metabolism of DDT in the bug were made at a dosage level which was indicated by the foregoing dosage-mortality data to be about the maximum sublethal dosage for peanut oil emulsions of DDT. Consequently, the bugs would not be killed and the physiological mechanism involved in metabolizing DDT would suffer a minimum effect if DDT poisoning should be found to be a factor limiting the ability of the bug to metabolize the compound. The data in table 2 show that the insect metabolizes a considerable portion of the total dose, 34 per cent or 34 μg./g. of body weight, 10 minutes following the injection. After this extremely rapid initial metabolization, the rate decreased to such a low level as to require a period of 48 hours to metabolize an additional amount comparable to that which occurred in the first 10 minutes following injection.

The data in table 2 might indicate that only a certain portion of the total dosage applied was immediately available to the metabolizing mechanism of the insect, and therefore, further quantities were metabolized only as they became available. If this should be true, then the data in table 2 do not indicate the capacity or rate at which the metabolic changes occur. Tobias *et al.* (1946) reported that dosages of DDT injected into the American roach varied in their effect upon the insect depending upon the type of solvent employed. For example, they found that the LD-50 for DDT injected in acetone solution was between 5 and 8 μg./g., whereas when peanut oil emulsions of DDT were injected into roaches, the LD-50 was 85 μg./g. of body weight. Tobias *et al.* attribute this great difference in effect to the possibility that the peanut oil may act as a protective mechanism, retaining DDT in solution as a sort of storage reservoir. It was, therefore, assumed that if a solvent such as peanut oil could protect the insect from DDT poisoning, it might protect the DDT to a certain extent from the metabolizing mechanism of the insect.

Based upon the results of Tobias *et al.* and from the above findings, it seemed advisable to study the metabolism of DDT when injected into the insect in acetone solutions. Using acetone as a solvent for the DDT it was assumed that all of the DDT injected into the insect would be immediately available to the DDT metabolizing mechanism in the form of a finely divided suspension in the body fluids of the insect.

In studying the metabolism of DDT-acetone solutions, equal amounts of DDT were injected into both living and dead bugs. The dead bugs used in these experiments were killed immediately before injection by immersion in boiling water for 3 minutes. The data in table 3 show that from 75 to 91 per cent of the DDT was recovered in the dead bugs. In the living bugs, when the DDT dosage did not exceed 100 μg./g. of bug, from 80 to 100 per cent of the DDT was metabolized within 90 minutes following injection. This DDT loss represents approximately twice that lost when 100 μg./g. was injected in a peanut oil emulsion over the

Table 3.—DDT recovered from bugs 90 minutes after injection with DDT-acetone solutions.

DOSAGE DDT μG/G. BUG	μG. DDT/G. BUG RECOVERED FROM	
	Dead Bugs[1]	Living Bugs
100	91	0
100	85	20
100	76	0
100	86	0
100	78	14
200	191	162
200	180	124
200	176	141
200	184	155

[1] Bugs were killed previous to treatment by boiling for 3 minutes in water.

same period of time. When a dosage of 200 μg./g. in acetone was injected, an average of 54.5 μg./g. was destroyed by the bugs or 27 per cent of the actual amount injected.

The data presented in table 3 point to certain significant features of DDT poisoning and metabolism in the milkweed bug.

1. The milkweed bug has the capacity to metabolize 80 to 100 per cent of a dose of 100 μg. DDT/g. when injected in an acetone solution within the first 90 minutes following treatment. Since this dosage is sufficient to produce a high, if not complete, mortality in the treated insects it may be concluded that the ability of the insect to metabolize completely a fatal dose in such a short period of time is not an effective protective measure. It would seem, if the metabolic products of DDT are non-toxic to the animal, that the chain of physiological disturbances initiated by DDT resulting in death are the consequence of the presence of DDT in the insect for a period of time considerably less than 90 minutes in the case of the large milkweed bug.

2. The fact that bugs injected with DDT-acetone solutions immediately after being killed by immersion in boiling water, yield nearly quantitative amounts of the original dose indicates that the metabolism of DDT is dependent upon certain intact physiological systems of the living insect. These results also illustrate the reliability of the method to recover unchanged DDT from the bug tissues.

3. Since the application of DDT-acetone solutions to the insect in dosages approximating twice the LD-100 markedly reduced the ability of the insect to metabolize the compound, it would appear that the metabolic products are of no significance in the role of DDT poisoning.

The data presented in tables 2 and 3 refer to the metabolism of DDT in the bodies of the insects, but do not indicate the nature and amounts of the metabolic products. It was originally assumed that the metabolic products of DDT in insects would be found to be the same as those reported in similar studies involving various warm blooded animals, but such was not the case. In all instances where analyses were made on DDT treated insects, the extractions and analyses were carried out in such a manner as to permit the detection of quantities of the known and certain suspected metabolic products if they should exist in quantities of 5 μg. or more.

From the results of the analyses there is no evidence that DDT is metabolized in substantial quantities into DDE and DDA as proposed by White and Sweeney (12), nor into p,p′-dichlorodiphenylmethane, 4,4′-dichlorobenzohydrol, 4,4′-dichlorobenzophenone, or p-chlorobenzoic acid as suggested by Schechter *et al.* (3) as possible metabolites. Since it is possible that the DDT metabolites might not respond to treatment by the Schechter method, extracts of DDT treated insects were studied with the ultraviolet spectrophotometer in hopes of detecting compounds with characteristic absorption in this range.

The results of 60 examinations made upon extracts from DDT treated insects failed to show the presence of any compound other than DDT which absorbed in the ultraviolet range.

Since it is evident that in the living milkweed bug, DDT is not metabolized into DDE or DDA, further tests were conducted to determine, if possible, the metabolic fate of DDE and DDA when injected into milkweed bugs. p,p′-Dichlorodiphenylmethane was also included in this series of tests. The extractions and analyses were identical to those used for DDT.

The results of these tests showed that DDE did not appear to be toxic to adult milkweed bugs when administered in dosages of 100 μg./g. either in peanut oil emulsions or in acetone solutions. By the Schechter method, the analyses of choroform extracts from DDE treated living and dead bugs yielded approximately 50 per cent of theoretical quantities of DDE (Table 4) when assayed 90 minutes after injection. The extracts prepared for assay by the Schechter method all gave red colors and typical DDE absorptions at 520 mμ. However, when extracts made 90 minutes following injection were subsequently analyzed in the ultraviolet spectrum, it was found that while only DDE was recovered from the dead bugs, the absorption curve for the extract of the living bugs showed a small amount of metabolite "A" (maximum absorption at 2465 Angstroms) and an unidentified com-

pound which had a maximum absorption at 2325 Angstroms. These absorption curves are shown in figure 2. This new compound was retained in the chloroform extract throughout the analyses and was apparently insoluble in concentrated sulfuric acid or 2 per cent sodium hydroxide. The presence of this unidentified compound has been confirmed in three separate tests. The water extracts of the metabolite "A" treated insects did not reveal any abnormal products when examined by either the Schechter or ultraviolet methods.

Table 4.—DDE and DDE metabolite recovered from bugs injected with 100 μg./g. in acetone solution.

TIME INTERVAL INJECTION AND EXTRACTION	μG. DDE/G. BUG FROM DEAD BUGS[1]	μG. OF DDE PLUS DDE METABOLITE/G. FROM LIVING BUGS
90 minutes	46	42
"	54	58
"	51	55
24 hours	66	36

[1] Bugs were killed previous to treatment by boiling for 3 minutes in water.

The fact that DDE or its metabolite is stable in the living insect for a period of time greater than that required for the metabolism of an equivalent dosage of DDT is evidence that DDE is not an intermediary metabolite of DDT or it would have been found in the DDT treated insects.

DDA peanut oil emulsions and DDA-acetone solutions did not show any toxicity to the milkweed bug when injected at dosages of 100 μg./g. Extracts of treated insects analyzed by the Schechter method showed there was a 60 per cent loss of this compound one hour after injection and an 80 per cent loss at the end of 48 hours when the compound was applied in a peanut oil emulsion. In most cases when the DDA was applied in acetone solution there was 72 to 100 per cent loss within 90 minutes after injection. These results of the metabolic effects by the bug on DDA-acetone solution are shown in table 5.

Products other than DDA were not found by either the ultraviolet or Schechter methods of analysis.

Since DDA is rapidly metabolized by the insect, it must be concluded that this compound cannot represent the end product of any substantial quantity of DDT metabolism in the milkweed bug.

Table 5.—DDA recovered from bugs 90 minutes after injection with 100 μg./g. in acetone.

μG. DDA/G. FROM	
Dead Bugs[1]	Living Bugs
78	0
52	0
58	0
48	16
82	28

[1] Bugs were killed previous to treatment by boiling for 3 minutes in water.

p,p'-Dichlorodiphenylmethane applied in acetone solution at a dosage of 100 μg./g. did not appear to be toxic to milkweed bugs. Furthermore, the compound injected into living bugs was completely destroyed within 90 minutes after injection. The examination of the water and chloroform extracts from insects treated with the compound failed to show the presence of any material which could be considered a metabolic product.

Living milkweed bugs were homogenized and the *breis* were treated with DDT on the basis of 100 μg./g. of *brei*. When the *breis* were extracted 90 minutes later and subsequently analyzed it was found that the amounts of unchanged DDT recovered were near theoretical quantities and the same as that recovered from dead bugs which had received identical treat-

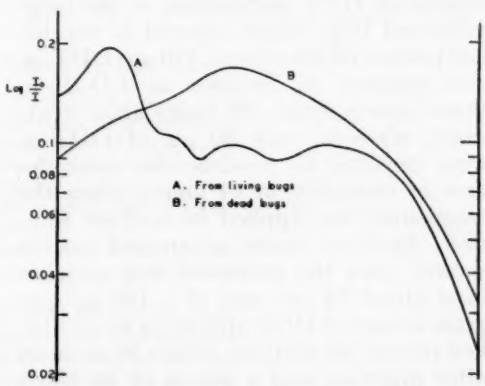

FIG. 2.—Absorption curves obtained from chloroform extracts of living and dead bugs injected 90 minutes previously with 100 gammas of 1-dichloro-2,2-bis(p-chlorophenyl) ethylene per gram of body weight.

ment. It is evident that the intact living milkweed bug is necessary for the normal rapid metabolism of DDT.

Further to confirm the presence or absence of DDT in the extracts of treated bugs, a bioassay was made. Living and dead milkweed bugs were injected with DDT-acetone solutions at dosages of 100 μg./g. of bug. After 90 minutes they were macerated and extracted by the same procedure as described for preparation of material for the colorimetric and ultraviolet analyses. Adult house flies were introduced into 25 ml. flasks coated with the residues from bug extracts and confined there for ten minutes. The flies were then transferred to clean vials. The results of these tests showed that when the flies were subjected to the residues of chloroform extracts from the DDT treated dead milkweed bugs they showed signs of typical DDT tremors within 10 minutes and died within 12 hours. The flies that were exposed to the residues from the DDT-treated living milkweed bugs were unaffected. This confirms the results of the colorimetric analyses made previously which showed that most, if not all, of a 100 μg./g. dose of DDT was metabolized within 90 minutes after treatment. It furthermore shows that chloroform extracts from live bugs previously treated with DDT do not contain toxins which may be picked up by insects walking on contaminated surfaces.

SUMMARY.—The development of a color test for DDT and certain of its suspected metabolic products by Schechter *et al.* made it possible to study certain aspects of DDT metabolism in the large milkweed bug. When injected in emulsified peanut oil emulsions, 170 μg. DDT/g. was required to produce an LD-50 in these insects within 96 hours after treatment, whereas, only 60 μg. of DDT/g. were required to produce the same degree of mortality in 24 hours, when the compound was applied in acetone solution. Analyses made on treated insects showed that the milkweed bug metabolized about 34 per cent of a 100 μg. per gram dosage of DDT applied in an emulsified peanut oil solution within 90 minutes after injection and a period of 48 hours was required for the insect to metabolize an additional equivalent amount. On the other hand, identical dosages of DDT applied in acetone solutions were metabolized to the extent of 80 to 100 per cent within 90 minutes after injection. It would, therefore, appear that peanut oil has the effect of limiting the availability of DDT to the metabolizing mechanism and at the same time acting to protect the insect from the potential toxicity of the injected dose. The ability of the insect to completely metabolize a lethal dose of DDT in a relatively short period of time would indicate that the prolonged fatal poisoning symptoms of DDT are the result of the presence of unmetabolized DDT for a period of short duration.

DDT applied in acetone solutions at a dosage of 200 μg./g. resulted in the metabolism of only 54 μg. or 27 percent of the total dosage within 90 minutes. Thus, DDT dosages in excess of the maximum which the insect can readily metabolize have the effect of inhibiting the DDT metabolizing mechanism. These results also indicate that DDT as such rather than a DDT metabolite is responsible for the poisoning symptoms observed in treated insects.

It was found possible to recover nearly theoretical quantities of unchanged DDT from bugs killed by boiling for 3 minutes in water before injection with DDT-acetone solutions. Homogenized tissues of bugs treated with various quantities of DDT were also found to yield practically theoretical quantities of unchanged DDT. It is, therefore, concluded that the normal rate of metabolism of DDT is dependent upon the intact living organism.

Colorimetric and ultraviolet spectroanalyses of both solvent and water extracts of bugs treated with DDT failed to show the presence of the expected metabolites, namely 2,2-bis(p-chlorophenyl)-1,1 dichloroethylene) and 2,2-bis (p-chlorophenyl) acetic acid, which have been recovered from various tissues and products of DDT treated warm blooded animals. When the former was injected into the milkweed bug in acetone solutions at dosage levels of 100 μg./g. it was possible to recover a product which by the Schechter method of analysis appeared to be the same but which, upon examination of the extract in the ultraviolet spectrophotometer, was found to contain in addition to 2,2-bis(p-chlorophenyl)-1,1-dichloroethylene an unknown compound suspected to being a metabolite with a peak absorption of 2325 Ångstroms. The

fact that this compound can be recovered in substantial quantities as long as 24 hours after it has been injected into the bug is considered to be good evidence that DDT does not metabolize stepwise from 1-dichloro-2,2-bis(p-chlorophenyl) ethylene to 2,2-bis(p-chlorophenyl) acetic acid the latter compound in extracts of DDT treated insects would have been detected.

Milkweed bugs injected with 2,2-bis(p-chlorophenyl) acetic acid at dosages of 100 μg./g. extracted and analyzed 90 minutes later showed that 72 to 100 per cent of the dose was not recovered. Since the compound could be recovered in near quantitative amounts from treated dead bugs and bug *breis*, it may be concluded that the compound is not an end product of DDT metabolism in this insect, but that, like DDT, it is readily metabolized by the treated living insect.

One other suspected degredation product of DDT, namely p,p'-dichlorodiphenyl methane, could not be detected in the analyses of DDT treated insects but like the 2,2-bis(p-chlorophenyl) acetic acid was found to be quickly metabolized by the living insect.

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PROFESSOR G. M. BENTLEY RETIRES

The usefulness of this Association up to very recent years is to a very large degree, the product of the thinking, planning, and activities of the pioneers and a small group of zealots that followed in their footsteps. In this latter category, Gordon M. Bentley has held a consistent place since 1904 when he was elected an associate member.

Always willing to give unstintingly of his time, he has served in many capacities as an officer and on innumerable committees.

Now that he is retiring as State Entomologist and State Pathologist of Tennessee, and Professor and Head of the Department of Entomology at the University of Tennessee, it is desirable that this Association acknowledge its debt to him and wish him the peace and contentment that is supposed to be the reward of an active life. His many civic, fraternal, and religious activities will provide abundant interests to supplement the companionship of his wife, children, and grandchildren.

The Use of Fluorescent Pigments in a Study of the Flight of the Japanese Beetle

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The Japanese beetle, *Popillia japonica* Newm., was first found in Ohio in 1931 at Cleveland and Columbus. By the end of 1942 it had been taken from 60 different locations all completely isolated from each other. Fifty-one of these isolated points of infestation were found in the eastern half of the state or in an area of approximately 20,370 square miles. If these infestations were evenly spaced over this area, they would be about 20 miles apart. Since several of them were actually separated by only a few miles, it was thought that they would be united, by flight of the beetle, into one continuous infested area in a matter of a few years. However, most of the infested areas have remained separated from each other with a considerable section of uninfested area between them. These peculiarities in the nature of the distribution and accumulation of the insect since its introduction in Ohio have led to a study of its migratory habits.

Preliminary Migration Studies.—Preliminary adult migration studies were made in 1943 when several thousand beetles were rolled in chrome dust and released. Of this number, only two recoveries were made. These were taken in traps located about 50 feet from the point of release. In the same year quick-drying lacquers, such as finger-nail polish, were also tried by applying a small amount to the thorax. The beetles thus marked would fly a short distance, drop to the ground, and immediately burrow into the soil. In checking upon several of these specimens in the soil, it was found that all of them had died about two inches beneath the soil surface. Since none of these beetles were taken in the traps, although many were located near by, it appeared that these lacquers were extremely toxic to the beetles and hence were discarded.

In search for a more suitable material for this purpose during the winter of 1943, several fluorescent pigments in both powder and lacquer form were found that worked very well when used in tests. These pigments show up as ordinary colors under natural light whereas they become very brilliant when exposed to the black light. Laboratory tests readily revealed that it was possible to pick out a single marked specimen in a quart of beetles without much difficulty.

Investigations in 1944.—The 1944 migration studies were conducted in the Cleveland area. These investigations consisted of marking a large number of beetles at weekly intervals during July and August with different colors and releasing all such marked beetles from one central point in the village of Bratenahl. The beetles used in these tests were collected from host plants located near the release points.

The pigment used on July 3 and 4 is known as invisible green powder, a product in common use by law enforcement officers. Beetles marked with this material could not be detected from unmarked specimens under natural light but under the black light a very tiny speck on the insect was very readily seen. The material used on July 11, known as blue sulphide phosphor, was also a powder but it did not adhere to the beetles. Furthermore it lost its fluorescence in a short time after being exposed to the sunlight. These findings were made by conducting a few laboratory tests with the pigment after no recoveries were made in the field. The other four materials used were lacquers.

The dust materials were applied by rolling a known number of beetles around in a jar with a small amount of dust. When the beetles were thoroughly covered they were released by emptying the jar upon a large section of plywood. Those that did not fly away were not counted in the number that were considered in the test. The lacquers were applied with a match stick dipped into the liquid pigment and touched to the beetles as they emerged from a box placed upon a section of plywood. The beetles that could not fly away were not counted. These materials did not seem to affect the flight or general behavior of the adult, unless too much of the lacquer was applied so that the wings were immobilized.

In order to determine the direction and

Table 1.—Record of recoveries follow release of marked beetles at Bratenahl, Ohio, in 1944.

Date Marked and Released	No. of Beetles Marked	Material Used	Beetles Recovered			
			Days After Release	No. Recovered	Av. Distance from Release Point (Ft.)	
7-3	1170	Invisible green powder	1	2	125	
7-4	1000		7	5	1513	
			15	15	489	
			16	16	944	
			17	3	633	
			20	12	1667	
			21	1	1100	988 av.
7-11	6644	Blue sulphide phosphor powder		0		
7-17	600	Signal green lacquer	13	7	205	
7-18	2200		15	2	700	
			15	2	2350	
			16	2	850	
			21	4	1656	
			22	2	1313	
			34	2	2013	
			35	2	2800	
			36	2	2425	1451 av.
7-25	1885	Fire orange lacquer	6	15	538	
			7	32	1592	
			8	1	1800	
			9	11	564	
			14	4	1594	
			15	1	1825	
			16	1	5400	
			19	1	1820	1175 av.
7-31	1040	Invisible blue lacquer	2	8	713	
8-1	948		7	11	1636	
			8	4	1156	
			9	4	4350	
			12	1	1800	1707 av.
8-7	420	Neon red lacquer	13	10	808	
8-8	620		14	5	850	
			15	2	3050	1102 av.
	16517		14.8	190	1245	

approximate distance these marked beetles migrated, traps were located at intervals of 150 to 800 feet apart in the village of Bratenahl and at intervals of 0.25 to 2 miles apart in the various municipalities to the east, south, and west of the village. In all, 681 traps were used in this test. The beetles captured in traps in Bratenahl were collected twice a week and examined under the black light for marked specimens, while the trap cooperators in the outlying sections sent their collections in to one central point once each week for examination under the black light.

The result of these studies is shown in tabular form in table 1.

By using a different color each week, it was possible to determine approximately how long each beetle was in the field before being collected, the distance each beetle migrated after being marked, and the variation in the behavior of the beetles during different portions of the observation period.

These data show that the marked beetles were in the field for a period of 1 to 36 days with an average of 14.8 days before being caught in a trap. The distance of these traps from the point of release ranged from 50 to 5600 feet and averaged 1245 feet for all specimens studied. These data seem to indicate also

that the greatest activity occurred with the lot of beetles marked on July 25 since 3.5 per cent of the beetles marked and released on that date were captured. The lots marked on July 31 and August 1 traveled the greatest average distance before being taken in traps.

EFFECT OF WIND UPON DIRECTION OF MIGRATION.—During the period in which the beetles were marked and released the wind direction, at the point of release, was recorded 3 times during the day with the idea of determining the effect of the wind on the direction of flight. These readings were taken at 10:00 A.M., 12:00 Noon, and 3:00 P.M., the periods which represent the approximate beginning, peak, and the end of beetle flight for the day. Table 2 shows the number of times the wind was blowing from a given direction during the period and the number of beetles taken in traps located in a given direction from the point of release.

Table 2.—Recovery of adult beetles in relation to wind direction.

POINTS OF COMPASS	NO. OF BEETLES TAKEN IN TRAPS LOCATED IN THE DIRECTION INDICATED FROM RELEASE POINT	NO. OF TIMES THE WIND WAS BLOWING FROM DIRECTION INDICATED
N	40	0
NNE	46	1
NE	23	3
ENE	11	0
E	0	0
ESE	0	1
SE	0	7
SSE	0	7
S	0	1
SSW	0	6
SW	5	28
WSW	18	5
W	18	5
WNW	6	3
NW	13	34
NNW	10	14

These data show that the greatest number of beetles were taken in traps located to the north-northeast, north, and northeast from the point of release while the wind blew from the northwest, southwest, and north-northwest for the greatest number of times during the beetle flight period. The immediate effect of the wind upon migration was noted at one time during this study when the wind blew from the southeast and south-southeast for a period of 5 consecutive days. One of the release periods occurred at the beginning of this period. Two days later recoveries of marked beetles were made from the west and west-southwest of the release point, and recoveries continued to be made from these directions for a period of 7 days. As soon as the wind shifted back to the northwest or southwest, the recoveries were made in the opposite direction.

A few observations regarding the effect of wind velocity upon the flight of the beetles indicated that the greatest migration took place when the wind was blowing at the rate of about 3.5 miles per hour while very little migration or movement took place when the wind rose to 7 to 8 miles per hour.

INVESTIGATIONS IN 1945.—In 1945 migration studies were conducted in the Ewing Nursery at North Salem, Ohio. The procedure and technique in marking and releasing the beetles were similar to those employed in 1944. In this study only 260 traps were used. Fifty were placed at intervals of 100 to 300 feet apart in the Ewing Nursery and the remaining number or 210 were located at intervals of 0.5 to 1 mile apart in all directions around the nursery. All traps were checked twice a week and the collected beetles were exposed to the black light. The data in table 3 show the result of these studies.

In this experiment, 174 or 1.9 per cent of the marked beetles were recovered in traps after being in the field for a period of 1 to 13 days or an average of 5.5 days. The recoveries were made in traps located from 30 to 1200 feet or an average of 194 feet from the release point. The low per cent of recoveries obtained during the latter part of the season might possibly be due to the migration of the beetles beyond the area of trap concentration and out into the area where the traps were placed some distance apart thus lessening the chance of recovery. It is possible however, that the migration distance was restricted by a 7 to 8 mile wind that prevailed throughout the period of investigation in this area. The relatively high wind velocity is probably the reason for the low average distance between the release and recovery points as compared to the distance recorded in the Cleveland studies.

EFFECT OF WIND DIRECTION UPON MIGRATION.—The effect of the wind upon the direction of migration of marked

Table 3.—Record of recoveries following release of marked beetles at North Salem, Ohio in 1945.

Date Marked and Released	No. of Beetles Marked	Material Used	Beetles Recovered		
			Days After Release	No. Recovered	Av. Distance from Release Point (ft.)
7-3	2215	Pearl white lacquer	2	20	343
			3	32	209
			4	17	195
			8	1	300
			9	2	60 244 av.
7-9	2230	Invisible green powder	1	26	117
			3	28	182
			4	8	229
			7	1	300
			8	2	195
			9	3	500
			13	1	240 177 av.
7-16	2474	Neon red lacquer	1	8	154
			2	2	210
			7	4	143
			9	3	400 201 av.
7-24	2012	Horizon blue lacquer	1	2	90
			2	8	158
			3	3	220
			13	3	140 156 av.
	8931		5.5	174	194

beetles is shown in table 4. The wind direction records in this area were also taken three times a day, namely at 9:00 A.M., 12:00 noon, and 3:00 P.M.

These data show that the wind blew from the northwest, west, and north the greatest number of times during the period of investigation and that the greatest number of marked beetles were recovered in traps located to the south and southeast from the point of release.

CONCLUSION.—These studies indicate that fluorescent pigments in dust or lacquer forms can be applied quite readily to the Japanese beetle adult without interfering with the insect's normal behavior. The beetles marked with these pigments can be distinguished readily in a large quantity of beetles without much difficulty. Therefore, this method of marking the beetles provided a simple means for studying the migration and flight of the insect. The data indicate that the adults generally fly with the wind. Observations on the effect of wind velocity tend to indicate that there was very little movement of the adults in winds of 7 miles or more per hour.

Table 4.—Record of beetle recovery as related to wind direction at North Salem, Ohio.

Points of Compass	Beetles Taken in Traps Located in the Direction Indicated from Release Point	Times Wind was Blowing from Direction Indicated
N	4	13
NE	13	1
E	24	5
SE	52	1
S	56	0
SW	9	4
W	11	20
NW	5	36

The data taken in the Cleveland area indicate that the spread of the insect by flight into new territory is limited to approximately 1 to 1.5 miles per year. However, it is probable that the migration distance would vary considerably with the climatic factors prevailing during the year.

Soil Treatments for Corn Rootworm Control

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The corn rootworm[1] experiments reported in this paper are a continuation of studies conducted in Nebraska during 1945, 1946 and 1947. In 1945 Tate & Bare (1946) obtained crop histories of 38 fields which had been in corn from 1 to 25 years. These fields were infested principally with the western species and crop rotation was found to give excellent control. Hixson *et al.* (1947) reporting on studies made in 1946, chiefly with the western species, confirmed the findings of Tate & Bare and in addition determined that an application of 40 to 80 pounds per acre of nitrate fertilizer or a heavy application of manure, reduced lodging and increased yields. Despite the use of these findings in educational programs many farmers continued to plant corn in the same field year after year and rootworm injury remained serious. Some experiments conducted in 1947 were designed to determine the effectiveness of certain insecticides as soil treatments in the control of all three species. Data collected and published by Hill *et al.* (1948) showed that applications of benzene hexachloride at rates of 8 ounces to 2.4 pounds of the gamma isomer per acre gave high larval kills and greatly reduced stalk lodging. DDT was found to be comparatively ineffective. Actual corn yields were not significantly increased due apparently to soil variations within the test plots. Corrected yields based on corn not mechanically harvestable due to lodging did, however, show definite increases where benzene hexachloride was used.

During the 1948 season experiments were designed to determine if corn rootworm control with benzene hexachloride would result in an increase in actual corn yield. Two additional chemicals, toxaphene and rotenone, were also tested for insecticidal efficiency against rootworm larvae. Nitrogen as a nitrate was applied to certain plots to determine the combined effects of insecticides and fertilizers.

PROCEDURES AND METHODS.—Two test fields were established and treated. Each test area included 10 treatments and an untreated control replicated five times giving a total of 55 randomized plots. Each plot contained six rows 50 feet long. There was a 10-foot untreated alley between each of the five series of plots.

Insecticide dosages included a 10 per cent gamma isomer wettable powder of benzene hexachloride[2] at 1 and 2 pounds of gamma isomer to the acre, a 40 per cent xylene-kerosene emulsion of toxaphene[3] at 1, 2 and 4 pounds of toxaphene to the acre and a cube powder containing 5 per cent rotenone[4] at 5 pounds of rotenone to the acre. Fertilizer was ammonium nitrate applied at a rate of 40 pounds of actual nitrogen to the acre.

Insecticidal treatments were applied as sprays to the surface of the soil just in advance of disking and planting. The sprays were delivered through a 10-foot hand-operated spray boom at 100 to 150 pounds pressure. Six, number 3 fan-type nozzles gave an application rate of approximately 100 gallons of spray per acre from an estate type sprayer. Nitrate fertilizer treatments were made at the time of the second cultivation with a hand-operated fertilizer applicator on each side of the rows. The applicator deposited the material in a band just below the surface of the soil.

Results of the treatments were recorded in three different ways. In mid-July four randomly chosen stalks in each plot were cut off at the base and samples consisting of the roots and surrounding soil 7 inches square by 5 to 6 inches deep were carefully removed. Larvae were separated from the soil and litter in the field by a brine flotation, preserved in 70 per cent alcohol and counted in the laboratory. Records of lodging were taken just prior to harvest. Yield records were also taken and data were treated statistically.

RESULTS.—Fertility levels in the two experimental fields were considerably different. This difference necessitated a separate analysis of the results obtained in each field. The two are referred to as the C. E. Anderson field near Lexington,

[1] *Diabrotica longicornis* (Say), the northern corn rootworm, *D. virgifera* Lec., the western corn rootworm and *D. undecimpunctata howardi* Barber, the southern corn rootworm.
[2] *Pennsylvania Salt Mfg. Co.*, Philadelphia, Pa.
[3] *Hercules Powder Co.*, Wilmington, Del.
[4] *Miller Chemical Co.*, Omaha, Neb.

Table 1.—Results of corn rootworm control tests with soil treatments in 1948, Cowgill field at Wood River, Nebraska.

TREATMENT PER ACRE	AVERAGE NO. CORN ROOTWORMS PER SAMPLE	PER CENT STALKS LODGED 30° OR MORE	YIELD[1] BUSHELS PER ACRE
Benzene hexachloride—2 lbs. Gamma	2.1	1.0	75.4
Benzene hexachloride—1 lb.	4.7	0.6	73.7
Benzene hexachloride—1 lb.+N—40 lbs.	4.8	0.6	83.8
Toxaphene—4 lbs.	16.7	12.6	72.4
Toxaphene—1 lb.	32.9	41.6	70.8
Toxaphene—2 lbs.	29.9	38.2	65.3
Toxaphene—2 lbs.+N—40 lbs.	26.3	20.4	83.6
Rotenone—5 lbs.	32.3	49.4	73.3
Rotenone—5 lbs.+N—40 lbs.	38.9	55.6	78.7
N (nitrogen) 40 lbs.	32.1	55.0	77.2
Control (no treatment)	37.6	52.8	66.6
Difference required for significance at 19:1 odds	8.0	20.8	7.3

[1] Calculated on the basis of 15.5 per cent moisture.

Nebraska and the Paul Cowgill field, at Wood River, Nebraska.

Fertility of the Cowgill field,[1] on Hall silt loam, was apparently quite low as all plots receiving nitrate fertilizer gave a significant increase in yield. These yield increases were not correlated with decreases in rootworm populations or stalk lodging. The data presented in Table 1 show that in the absence of nitrogen only the heavy dosage of benzene hexachloride, 2 pounds gamma per acre, gave significant increases in yield that correlated with reductions of rootworms and lodging.

The Anderson field,[1] also on Hall silt loam, seemed to be considerably more fertile than the Cowgill field as a direct nitrogen response was not obtained. Table 2 presents the data taken from this field. All of the benzene hexachloride treatments gave significant increases in yield that correlated with decreases in rootworms and lodging.

[1] Planted to Pioneer 300 hybrid.

Data from the two fields indicate a rather interesting trend concerning the use of benzene hexachloride for the control of rootworms. Dosages that drastically reduced the population of the insects and subsequent percentage of stalks lodged did not necessarily have a significant effect upon the corn yield. This is indicated by the fact that one pound of gamma benzene hexachloride per acre greatly reduced rootworms and lodging in both fields, but in the absence of fertility failed to give a significant increase in yield.

Table 2.—Results of corn rootworm control tests with soil insecticides in 1948, Anderson field, Lexington, Nebraska.

TREATMENT PER ACRE	AVERAGE NO CORN ROOTWORMS PER SAMPLE	PER CENT STALKS LODGED 60° OR MORE	PER CENT STALKS LODGED 40° OR MORE	YIELD[2] BUSHELS PER ACRE
Benzene hexachloride—2 lbs. Gamma	5.3	0[1]	33	104.9
Benzene hexachloride—1 lb.	9.2	0[1]	33	102.8
Benzene hexachloride—1 lb.+N—40 lbs.	11.0	0[1]	41	111.5
Toxaphene—4 lbs.	28.9	18	80	82.4
Toxaphene—1 lb.	42.5	45	93	67.7
Toxaphene—2 lbs.	37.5	42	94	86.4
Toxaphene—2 lbs.+N—40 lbs.	31.4	32	91	81.7
Rotenone—5 lbs.	40.7	50	96	78.7
Rotenone—5 lbs.+N—40 lbs.	34.7	33	89	79.1
N (nitrogen) 40 lbs.	29.5	38	89	76.8
Control (no treatment)	37.7	55	99	83.3
Difference required for significance at 19:1 odds	11.0	21.4	14.9	13.1

[1] Omitted in analysis of variance.
[2] Calculated on the basis of 15.5 per cent moisture.

Table 3.—Rootworm populations and lodging records for 1947 and 1948 on the Harold Fagot farm, at Lexington, Nebraska. Treatments were applied in the spring of 1947.

Treatment per Acre	1947		1948	
	No. Rootworms per Sample (July 31)	Stalks Lodged 30° or More (Oct. 16)	No. Rootworms per Sample (July 15)	Stalks Lodged 30° or More (Aug. 5)
Benzene hexachloride—2 lbs. Gamma	0.8	1.0%	2.2	16.7%
Benzene hexachloride—1 lb.	4.6	2.1	1.4	16.7
Benzene hexachloride—0.5 lb.	6.1	5.4	12.1	50.7
DDT				
10 lbs.	12.2	26.6	7.7	67.3
5 lbs.	17.4	38.8	7.7	70.0
Check				
(no treatment)	22.4	66.7	16.1	73.3
Difference required for significance at 19:1 odds	6.0	14.5	9.4	31.0

Heavy dosages of toxaphene, 2 and 4 pounds to the acre, gave significant reductions of rootworm populations and lodging but the reductions were not drastic and did not significantly affect yields.

POST-SEASONAL RESIDUES.—Additional observations and records were made during the past season on part of the field used in the soil insecticide tests reported by Hill *et al.* (1948). These data were taken on the Harold Fagot farm at Lexington, Nebraska to determine if benzene hexachloride would remain effective for more than one season. The possibility of obtaining this type of information was suggested in 1947 when lateral movement of emerging adult beetles caused a general infestation over plots treated with the chemical.

Data obtained in 1948 and presented in Table 3 indicate that soil treatments of benzene hexachloride applied in the spring of one year will affect at least two generations of the northern and western corn rootworms. No information was obtained as to what stage of the insect was affected by the post-seasonal residues. Additional studies should be conducted to determine whether the adult beetles, the overwintering eggs or the hatching larvae of the succeeding generation are killed.

CONCLUSIONS AND SUMMARY.—Soil insecticides tested in Nebraska indicate that benzene hexachloride applied at the rate of 1 to 2 pounds of the gamma isomer per acre will give control of corn rootworms for at least two seasons. Increased yields following insecticidal control of rootworms seemed to be dependent upon and directly correlated with soil fertility as expressed by available nitrogen. This may be construed as further evidence that crop rotation and the consequent maintenance of fertility has an important place in any corn rootworm control program.

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The Use of DDT for the Control of Chestnut Weevils

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The American chestnut, *Castanea dentata* (Marsh) Borkh, at one time flourished from the northern New England States and southern Ontario to the Gulf of Mexico. Nearly all forest stands of this tree, however, have now been killed by one or the other of two diseases. The loss of the American species directed attention to the possibility of replacing it with some foreign chestnut, and the United States Department of Agriculture has distributed a large number of blight-resistant chestnut trees of Asiatic origin for experimental planting in orchards and forests from New England to Georgia and in the Ohio Valley.

One of the most serious problems that has limited the growing of these Asiatic chestnuts for their nuts is the infestation by the chestnut weevils, which frequently destroy from 90 to 100 per cent of the nuts. Until a few years ago practical methods of controlling these pests were not available. The two weevils that cause the most injury are the small chestnut weevil (formerly called the lesser chestnut weevil), *Curculio auriger* (Casey), and the large chestnut weevil, *C. proboscideus* F. These weevils also feed on the chinquapins, *Castenea pumila* and *C. alnifolia*.

Since the mouth parts of the adults are situated at the end of the long, slender beak, they can obtain their food from beneath the surface of the bur. The females also use this beak to drill holes in the spiny covering of the bur in which to lay their eggs. The larvae feed within the nut and do not leave it until they are full grown. These habits make practically useless the stomach poisons that have ordinarily been applied to the surface of the leaf or bur to combat chewing insects.

The contact action of DDT on certain other insects suggested that this new insecticide be tested against chestnut weevils.[1] Accordingly, the Bureau of Entomology and Plant Quarantine began experiments at Beltsville, Md., in 1944. This paper presents the data obtained during four seasons in tests of DDT for the control of the weevils under field conditions and observations made on the activities of the adults.

Very few chestnut orchards now exist in the eastern states, and the scattered plantings consist mostly of a large number of the Asiatic seedlings, some of which have been top-worked to other Asiatic species and varieties. Many of these trees are grown for ornament, shade, or timber, rather than for nut production. Owing to these conditions and to a series of spring frosts since 1945, it has been impossible to conduct insecticide experiments on an adequate basis of replicated plots.

Exploratory Studies.—The first tests with DDT against the weevils were exploratory, and the time of spraying was based on habits of the adults as described by Brooks & Cotton (1929). According to these authors, the large weevil emerges from the soil when the chestnut burs are somewhat more than half grown, and oviposition follows soon thereafter. They stated that in the vicinity of French Creek, W. Va., the small chestnut weevil issues from the gound in May, but oviposition does not begin until the nuts are nearly full grown and most of the eggs are laid after the mature burs begin to open. This may be true in the case of attack against the American chestnut, but it appears that the burs of the Asiatic seedlings are at a much earlier stage of development when the eggs are deposited, as will be shown later in this paper.

On June 9, 1944, a large, low-hanging chestnut branch was given one application of a spray containing 4 pounds of DDT and 0.02 pound of sodium lauryl sulfate to 100 gallons of water. Neither the foliage nor the burs were injured. Subsequent tests with a spray made with a wettable DDT powder corroborated these results.

Timing of Spray Applications.—Applying DDT sprays at the proper time is very important. An examination in 1944 of many unopened chestnut burs disclosed that eggs of the small chestnut weevil were being deposited many weeks before the burs would open. It was also noted that great numbers of the larvae were leaving the nuts soon after the burs cracked open. Evidently these full-grown larvae had hatched from eggs deposited several weeks before the burs split.

[1] Suggestion first made by G. F. Gravatt, U.S.D.A.

Table 1.—Results of bagging chestnut burs to determine the time of oviposition of the chestnut weevils.

Orchard	Date of Bagging	Nuts Bagged	Nuts Infested With—	
			Small Weevil	Large Weevil
		Number	*Number*	*Number*
	1945			
Glenn Dale, Md.	July 9	52	2	5
	Aug. 1	46	4	2
	15	107	18	11
Fairfax, Va.	Aug. 21	110	22	13
	Sept. 12	123	63	11
	1946			
Glenn Dale, Md.	July 12	65	0	0
	18	40	0	0
	26	67	0	0
	Aug. 1	71	0	0
	9	29	1	0
	14	88	3	2
	23	53	18	2
	29	53	23	11
Fairfax, Va.	July 26	98	0	0
	Aug. 15	168	0	0
	Sept. 4	164	139	16
	1947			
Glenn Dale, Md.	Aug. 15	54	5	1
	25	38	8	0
	Sept. 2	24	7	1
	9	42	18	4
	15	56	29	7
	22	90	47	11
	29	143	83	22
	1947			
Fairfax, Va.	Aug. 26	35	9	1
	Sept. 10	58	25	4
	23	50	35	7
	Oct. 7	217	177	22
Elkton, Md.	Aug. 21	139	11	13
	Sept. 4	83	22	25
	18	116	21	35
	Oct. 1	108	31	44

Beginning in 1945, observations were made in the orchards at Glen Dale and Elkton, Md., and at Fairfax, Va., to determine the time of oviposition of the chestnut weevils. Cloth bags were tied over developing burs at intervals to prevent further egg laying in the nuts. At harvest the bags were removed and the nuts examined. Occasionally adults were hidden among the spines of some burs and were inadvertently enclosed in the bag. Therefore, all nuts in bags containing female adults that might have continued ovipositing were discarded. The approximate time prior to which the nuts were infested is shown in table 1.

Because it was difficult to obtain sufficient burs for bagging, the results of these studies were far from conclusive. They indicated, however, that many eggs had been deposited in the nuts before the burs had reached maturity. They also suggested that the seasonal histories of the two species are closely parallel. At Glenn Dale, Md., and Fairfax, Va., the small weevil predominated, constituting 69 to 90 per cent of the total numbers taken. At Elkton, Md., only 42 per cent of the weevils were of the small species.

SPRAY EXPERIMENTS IN 1944.—Shortly after adults of the large chestnut weevil first appeared in the orchards at Glenn Dale, Md., in 1944, six isolated trees were selected for treatment. Five trees were sprayed with 1 to 5 pounds of DDT plus 0.5 per cent by weight of sodium lauryl sulfate to 100 gallons of water, and the sixth tree was left untreated as a check. A coarse, drenching spray at a pressure of 400 pounds per square inch was applied in an attempt to force the DDT between the many spines of the burs. The DDT used was very coarse, and it was difficult to get a proper suspension. This formula was used, however, in preference to one which contained other ingredients that might have formed a protective coating over the particles of DDT. Heavy rains prevented later spray applications. Adult weevils obtained by jarring untreated trees were then confined in screen cages placed over the lower branches of the trees. At the end of each cage was a cloth sleeve which was tied to the limb to hold the cage in place.

The results obtained the first few days in the cages containing treated foliage were somewhat irregular, because of the small numbers of tests made, but all weevils of both species were killed within 6 days. The results indicate definitely that DDT is toxic to the adults of both species No consistent differences between species were noted.

Daily collections were made of mature nuts that dropped from the treated trees, and one-third of each collection was used as a sample in determining the percentage of wormy nuts. The holes in the shell through which the eggs were inserted are very difficult to detect at the time the nuts drop. The nuts were therefore held in wire baskets to permit most of the larvae to emerge before the final examination. All nuts not showing exit holes were cut open to find out whether they were wormy. A marked increase in clean nuts resulted from all treatments, an indication that DDT is a promising insecticide for use against the weevils. The treatment and infestation records are given in table 3, which also includes the results obtained in later years.

STUDIES OF DDT FORMULATIONS.—The difficulty encountered in applying DDT sprays to chestnut foliage and burs in the first spraying experiments in 1944 prompted certain work in an attempt to condition the material. Mixtures of DDT with equal quantities of various diluents were prepared in a micropulverizer.[2] Table 2 shows the physical properties of the various mixtures.

Table 2.—Physical properties of mixtures of DDT with various diluents, prepared in a micropulverizer for tests against the chestnut weevil.

DILUENT	SURFACE MEAN DIAMETER OF MIXTURE	BULK VOLUME	QUANTITY PASSING THROUGH U.S. NO. 80 SIEVE[1]	SURFACE MEAN DIAMETER OF DILUENT
	Microns	*Pounds*	*Per Cent*	*Microns*
Talc	6.4	106	94	2.7
Pyrophyllite:				
Batch 1	6.6	115	92	2.6
Batch 2	7.0	107	—	2.6
Frianite	6.1	111	48	—
Diatomite	1.1	250	20	0.4
Limestone	12.5	74	88	7.4
Walnut shell	14.0	111	94	18.0
Bentonite	6.2	66	96	3.0
Gypsum	10.0	82	89	5.4
Kaolin (colloidal N.F.)	1.8	118	85	0.7

[1] By dry sifting.

Sprays prepared from these mixtures in the proportion of 2, 4, and 6 pounds to 100 gallons of water were applied to bean foliage, and visual observations were made on their wetting, spreading, and sticking qualities. The mixture of DDT and kaolin appeared to be far superior to any of the others. It was easily wet with water, remained for a considerable time in suspension, spread very well on the foliage, and seemed to produce a good tenacious residue. Other kaolins were also tested, and from these materials kaolin type 41 was selected. Since 1945 it has been used in all field experiments for control of the chestnut weevils.

SPRAY EXPERIMENTS 1945 TO 1947.—Spring frosts in 1945 destroyed 95 per cent of the chestnut crop in the eastern states. Only six trees of different species and ages in the Government orchard at Glenn Dale, Md., had enough nuts for experimental purposes. A DDT spray was applied on August 20 and September 9. These sprays contained 4 or 6 pounds of 50 per cent DDT wettable powder plus 2 quarts of summer oil as a sticker to 100 gallons of water.

Spring frosts again damaged the orchards in 1946, destroying about 80 per cent of the possible chestnut crop, and leaving only eight trees in the Government orchard that were suitable for experimental purposes. A mixture of 2 pounds each of DDT and kaolin type 41 was used to 100 gallons of water. The time and number of applications were varied.

Sprays identical with those used in 1946 were applied in two orchards in 1947—the Government orchard at Glenn Dale, Md., and the VanReynold orchard at Elkton, Md. Spring frosts injured 50 per cent of the chestnut crop at Glenn Dale and 70 per cent at Elkton, and as a result only a few trees were suitable for the tests. The remaining trees were not sprayed.

The quantities of DDT used, the schedules followed, and the results obtained during the period 1944 through 1947 are summarized in table 3.

These results indicate clearly the effectiveness of DDT in chestnut weevil control, in spite of numerous discrepancies brought about by the small number and variability of the trees available for the tests. As might be expected, three applications, were more effective than one or two. Of the single applications, those put on in the latter half of August were much more effective than those made in the first half of September, presumably because most of the eggs had been laid by September.

These experiments gave fairly exact information on the relative abundance of the two species of weevils. At Glenn Dale the small chestnut weevil constituted 92 to 98 per cent of the population: at Elkton 61 per cent.

From the sample of mature nuts that were collected daily from count trees, it was possible to obtain a rough estimate of the numbers of larvae produced on each each tree. In 1946, from 1863 nuts on a tree sprayed three times, 429 larvae emerged, and from a comparable unsprayed tree having 2610 nuts 16,494 larvae emerged. In 1947, 1350 larvae were produced on 9 trees, with an average crop of 1361 nuts on trees sprayed three times, compared with 14,505 larvae in 2922 nuts on an unsprayed tree. These figures indicate that DDT sprays bring about large decreases in the numbers of weevils, and that the proper use of DDT sprays on all

[2] This work was done in cooperation with the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine.

Table 3.—Results of spray tests with DDT against the chestnut weevils in the government orchard at Glenn Dale, Md., 1944–1947.

Date	Pounds DDT per 100 Gallons of Water	Nuts in Sample	Larvae Emerging from Sample		Per Cent Wormy Nuts	Reduction in Injured Nuts as Result of Spraying
			Small Weevil	Large Weevil		
1944						
Aug. 14	1	533	1896	21	44	42%
	2	646	402	45	25	67
	3	712	421	5	18	76
	4	951	814	5	22	71
	5	1844	850	10	16	79
	0	976	3238	100	76	—
1945						
Aug. 20 and Sept. 9	2	660	434	38	30	57%
	3	305	285	58	22	69
	0	297	1164	61	70	—
1946						
Aug. 15 and 30, Sept. 11	2	621	131	12	9	90%
Aug. 15 and 30	2	371	171	23	19	79
Aug. 30 and Sept. 11	2	292	87	21	26	71
Aug. 15 and Sept. 11	2	949	553	190	43	53
Aug. 30	2	1267	1407	98	43	53
Aug. 15	2	1212	3207	66	43	53
Sept. 11	2	368	1832	53	58	36
	0	870	5364	134	91	—
1947						
Aug. 13 and 29, Sept. 12	2	4084	3817	234	30	66%
Aug. 13 and 29	2	2618	4255	151	52	40
Sept. 12	2	3029	9498	402	79	9
Aug. 13	2	2639	5049	198	51	41
	0	974	4714	121	87	—
		Van Reynold Orchard, Elkton, Md.				
1947						
Aug. 21, Sept. 4 and 18	2	1153	264	64	14	84%
Sept. 4 and 18	2	338	5	118	67	23
Aug. 21 and Sept. 18	2	149	18	59	34	61
Augl 21 and Sept. 4	2	669	102	12	51	41
Sept. 18	2	324	63	129	77	11
Sept. 4	2	270	303	67	56	36
Aug. 21	2	500	192	127	57	34
	0	338	152	118	87	—

host trees over a period of a few years would doubtless reduce the infestation to a point where fewer applications would be necessary for effective control of the chestnut weevils.

SUMMARY.—To supplant the American chestnuts which were killed by the chestnut blight, a few blight-resistant species were obtained from foreign lands. Foreign chestnuts would now be planted more extensively in certain districts if a practical control was available for two species of weevils that injure the nuts.

Observations in orchards on the activity of the adults indicate that oviposition extends over a period of several weeks, during which time the nuts must be protected. Although the investigations dealing with this phase of the study are far from complete, the evidence obtained varies somewhat from the published information. As a rule the small chestnut weevil was the predominant species. In one orchard this species constituted over 90 per cent of the total number of weevils.

Froma study of several diluents used in making a wettable DDT powder, it was found that kaolin type 41 mixed with equal parts by weight of DDT and conditioned in a micropulverizer provided a satisfactory spray. In field tests conducted over a period of four seasons, three applications of this mixture at the rate of 4 pounds to 100 gallons of water showed a high degree of control of both species of weevils in heavily infested orchards.

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Residues on Citrus Trees in Florida[1,2]

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Under Florida citrus conditions, purple scales, *Lepidosaphes beckii* (Newm.), and Florida red scales, *Chrysomphalus aonidum* (L.), as well as citrus rust mites, *Phyllocoptruta oleivora* (Ashm.) and citrus red mites, *Paratetranychus citri* (Mcg.), have been noted to increase abnormally following either the use of sprays containing copper, zinc, or lime, or the accumulation of residues such as road dust, fertilizer, etc. Some authors (Watson & Berger 1937; Winston *et al.* 1923) have attributed the increase following copper and zinc sprays to the fungicidal action of these materials. Thompson (1939, 1942) has considered this problem in some detail, and he has shown that general tree vigor was also a contributing factor. Thus, although the residues were important in themselves, the use of zinc and copper also resulted in trees with fewer nutritional deficiences, and vigorous, growing trees were found to be more satisfactory hosts for scale insects. Holloway & Young (1943) compared the effects of $CuCO_3$, $CuSO_4$+lime and $Al(SO_4)_3$ at different concentrations. They demonstrated that the amount of residue might be more important than the kind, and they were unable to find any relationship between red-headed fungus *Sphaerostilbe aurantiicola* and *Nectria diploa* and purple scale mortalities. A recent report by Fisher *et al.* (1949) appears to throw doubt upon the claims made by early workers (Watson & Berger 1937) in Florida citrus to the effect that red-headed fungi would effectively control purple and Florida red scales. However, she did report the presence of a chytrid (*Myiophagus* sp. Thaxter) on purple scales in Florida, and presented evidence to show that it was a factor in the natural control of purple scales. The study reported here is the beginning of a series of experiments designed to learn what the effects of spray residues are. Eventually it may be possible to make specific recommendations which will minimize any adverse results developing from the use of sprays which leave residues on the foliage and fruit. Purple scales were considered primarily, but general observations were made of other citrus insects during the course of the investigations.

Methods.—The experiment was designed to study several different materials all at the same amounts of residue per 100 gallons of spray. In this way, chemical differences between materials could be observed. Six treatments, including an unsprayed control and five sprayed plots, were used. Table 1 lists the materials and the amounts of each per 100 gallons of spray. The copper was in the form of a basic copper sulfate ($(Cu(OH)_2)_x\,CuSO_4$). All materials were micronized[3] prior to use, and with the exception of zinc sulfate and lime which reacted in the tank, all were of a particle size which generally measured less than 10 microns in diameter The experiment was in duplicate. One series of treatments was applied to Pineapple orange trees and one to Valencia orange trees. In both cases, 30 trees were selected for the experiment and divided

[1] Presented at the annual meeting of the Cotton States Branch of the American Association of Economic Entomologists at Baton Rouge, Louisiana, February 2, 1949.

[2] This paper is Part I of a series of papers in this field which are planned for Journal publication.

[3] Micronized through the courtesy of the Micronizer Company of Moorestown, New Jersey.

Table 1.—Pounds of ingredients used per 100 gallons of spray for each of six experimental treatments.

Treatment	Lbs. per 100 Gallons					
	$ZnSO^4$	Lime	Copper[1]	Pyrophyllite	Wettable Sulfur	Total
Zn-lime-pyrophyllite	3	1.5	—	1.5	—	6
Cu pyrophyllite	—	—	1.5	4.5	—	6
Zn-lime-Cu	3	1.5	1.5	—	—	6
Pyrophyllite	—	—	—	6	—	6
Wettable sulfur	—	—	—	—	6	6
Unsprayed	—	—	—	—	—	0

[1] $(Cu(OH)_2)_xCuSO_4$.

into 5 plots. Treatments were randomized within each plot in a similar manner to the method worked out on citrus by Spencer & Osburn (1948). Sprays were applied on February 12, 1948, and again on April 7 and 8, 1948. No other sprays or dusts were used on the Pineapple oranges, but an oil emulsion spray for scale control was necessary in July in the Valencia block. Two counts of purple scales were made prior to the first spray applications, and additional counts were made at intervals throughout the summer, fall, and early winter. Counts were also made to determine the percentage of mortality[1] due to chytridiosis throughout the same period. Scale counts were based on the microscopic examination of the scales on a quarter of the surface of 50 leaves selected at random from each tree. Each leaf was recorded as infested or non-infested. Identifiable male scales were not included in scale counts. Chytridiosis incidence was based on the examination of scale-infested leaves from each tree. Counts were made of the number of scales infected by the chytrid as well as the number of living scales present. Only females in late second or third instar were included in this count since it is only in these stages that chytridiosis can be recognized.

In November, 1948, the Pineapple oranges were run through the packing house at the Citrus Experiment Station and sampled for the amount of fruit infested with scale or marked by rust mite injury. Results of the sampling are presented in table 2.

EFFECTS OF RESIDUE SPRAYS ON PURPLE SCALE INFESTATIONS.—Tables 3 and 4 present the changes in scale populations in the two series of experiments. Since the populations varied initially, they were more satisfactorily expressed as a percentage of the original population. However, actual populations show changes similar to those presented here. Table 3 shows two distinct groups of treatments as classified by scale population changes. Infestations on the untreated controls showed less increase initially, and, during the summer, these decreased to lower levels than did those on the other treatments. Scale populations on the trees sprayed with pyrophyllite and wettable sulfur increased initially to high levels, but throughout the summer and fall months they followed a very similar pattern to the unsprayed plots. Higher scale populations were maintained over more prolonged periods on the zinc-lime and copper sprayed plots. Reference to Table 2 shows that the fruit from the zinc-lime and copper treated trees had more scale than that from the other three plots.

Table 4 shows the marked reduction in population due to the oil emulsion spray applied in July. Prior to this spray, in-

Table 2.—Rust mite injury and purple scale infestation on Pineapple oranges sampled in packing house.

TREATMENT	PER CENT OF FRUIT WITH RUST MITE INJURY			PER CENT INFESTED WITH PURPLE SCALE
	Free	Early Injury	Late Injury	
Zn-lime-pyrophyllite	38	27	35	7
Cu-pyrophyllite	18	31	51	8
Zn-lime-Cu	24	28	48	11
Pyrophyllite	43	44	13	2
Wettable sulfur	38	39	23	2
Unsprayed	35	44	21	2

Table 3.—Changes in purple scale populations following the use of residue sprays in 1948 in a Pineapple orange block.

MATERIAL USED	PER CENT INCREASE OR DECREASE AS COMPARED WITH THE JAN. INFESTATION					
	Mar. 9	June 16	Aug. 2	Aug. 23	Oct. 11	Dec. 14
Zinc-lime	57	47	45	32	6	27
Copper	56	49	44	44	7	17
Copper-zinc-lime	32	42	43	34	−2	0
Pyrophyllite	83	35	−37	−48	−54	−20
Wettable sulfur	70	28	−21	−51	−41	−45
Untreated	32	18	−52	−61	−68	−54

Table 4.—Changes in purple scale populations following the use of residue sprays in 1948 in a Valencia orange block.

MATERIAL USED	PER CENT INCREASE OR DECREASE AS COMPARED WITH THE JAN. INFESTATION				
	Mar. 5	June 18	June 29	Aug. 25[1]	Nov. 4
Zinc-lime	106	134	175	−66	−16
Copper	84	84	105	−74	−50
Copper-zinc-lime	111	227	204	−50	−12
Pyrophyllite	160	208	216	−79	−46
Wettable sulfur	103	109	136	−88	−67
Untreated	86	114	67	−83	−61

[1] Followed an oil spray.

[1] $\frac{\text{Scales affected by Chytriodiosis}}{\text{Scales affected by Chytriodiosis + living scales}} \times 100.$

creases were essentially like those in table 3. The final scale counts in November 1948 showed that the zinc-lime sprayed trees had the highest while the unsprayed trees and the sulfur sprayed plots had the lowest scale populations. In this series, the copper sprayed trees had little more scale than the unsprayed controls. The reasons why purple scales did not increase after this copper treatment cannot be explained at this time.

Table 5 presents the percentage of mortality due to chytridiosis for the various treatments. Table 5 shows a decrease in the amount of chytridiosis between February and April. By May, there were more chytrids on the unsprayed controls and on the trees sprayed with wettable sulfur and pyrophyllite than on the other treatments. Summer rains did not begin until late June in 1948, but by the end of July, chytrids were common on the pyrophyllite plots and on the unsprayed trees. At this same time, the copper and wettable sulfur sprayed trees held an intermediate position as regards the amount of chytridiosis infection, and there was very little chytridiosis on the trees sprayed with zinc and lime. At the end of August, the rate of chytridiosis was increasing on the copper sprayed trees, but at this time most of the scales affected with chytridiosis had only been recently infected as compared with an apparent infection of several weeks' standing in the sulfur, pyrophyllite, and unsprayed plots. At the same time, the zinc-lime treated trees still had markedly lower chytrid incidence and this differential remained evident in November when the amount of chytridiosis was decreasing in all plots.

Table 5.—Changes in the per cent mortality of purple scales caused by chytridiosis following the use of residue sprays in a Pineapple orange block.

	PER CENT MORTALITY					
	Feb. 4	Apr. 8	May 26	July 28	Aug. 25	Nov. 3
Zinc-lime	42.85	1.13	3.61	19.94	49.37	38.13
Copper	31.58	1.90	——	45.49	78.44	67.17
Copper-zinc-lime	35.31	.56	.72	7.52	47.15	48.24
Pyrophyllite	25.97	6.00	15.09	84.14	88.39	78.84
Wettable sulfur	39.04	2.37	8.08	50.84	79.97	73.39
Untreated	31.23	3.75	9.67	75.41	78.89	73.82

Table 6.—Changes in the per cent mortality of purple scales caused by chytridiosis following the use of residue sprays in a Valencia orange block.

	PER CENT MORTALITY				
	Jan. 28	Mar. 31	May 26	Sept. 27	Nov. 5
Zinc-lime	21.60	.46	.87	66.22	44.58
Copper	30.84	.66	1.30	64.59	40.75
Copper-zinc-lime	32.96	1.15	——	39.20	36.90
Pyrophyllite	17.93	3.38	12.93	79.44	49.06
Wettable sulfur	30.88	4.69	2.62	84.88	42.57
Untreated	26.99	7.10	13.04	84.69	34.28

In table 6 similar tendencies are evident. Chytridiosis decreased through April. There was some increase in May and this was particularly evident on the unsprayed and pyrophyllite sprayed trees. As in table 5, chytridiosis reached a maximum in September and decreased by November. In general, per cent mortality figures for the series in table 6 did not attain as high levels as those found in table 5. Scale populations were considerably lower in the Valencia series, and this may have been a factor in the lower chytridiosis infection rates. In spite of the oil spray applied to this series in July, it appears that the infection rate of chytridiosis followed similar trends in both series.

DISCUSSION.—The data in tables 3 and 4 demonstrate that residues of copper, zinc-lime, wettable sulfur, and pyrophyllite on citrus foliage resulted in increased numbers of purple scales as compared with unsprayed controls. It appeared that the chemical nature of the material determined the extent and duration of the scale infestation. These results are similar to the actual conditions observed in commercial grove practice. Here, apparently, the use of copper and zinc containing sprays necessitates a summer oil application for scale control. Where neither zinc nor copper is sprayed, regular oil applications are often unnecessary. Under field conditions, road dust, fertilizer, or in fact, any residue seems to contribute to a build-up of scales to a certain extent. Although any residue may result in scale increases, it appears that copper or zinc-lime sprays or both would be more hazardous than wettable sulfur when scale increases are the only consideration.

Since stages of the chytrid, *Myiophagus* sp., have been found in purple scales which were still alive, as well as in dead ones, there can be no doubt that this fungus is parasitic, and that it is a major factor in natural control under Florida conditions. However, the relationships between chytridiosis and scale population

changes in the present experiments cannot be satisfactorily explained. In the Pineapple orange block where no oil spray was applied, there is an inverse relationship between chytridiosis and scale population changes on all treatments except the copper sprayed plots. That is, following high mortality the number of infested leaves decreased. In September, in the other series, the rate of chytrid infection was so high that scale decreases would have been expected. However, this was not the case and the scales actually increased. Further data are essential. It seems necessary to consider the possibility that such an incidence of chytridiosis may inhibit the rate of scale increase, but may not be sufficient in itself to reduce the purple scale infestation. Unpublished data indicate that in citrus groves in Florida where no copper, zinc, or oil emulsion sprays are used, purple scale populations reach a maximum during the early summer and begin a decline during the period between July and September. The intensity of the infestation in the early summer and the extent to which it declines in the late summer and fall is probably a function of a number of factors. The only known and substantiated factor is chytridiosis. Fisher *et al.* (1949) reported at least one other fungus (*Hirsutella* sp.) which apparently attacked and killed scale crawlers. It is possible that this fungus may work in conjunction with chytridiosis to induce scale mortalities which result in a lowering of the population levels. All of the factors involved in the build-up of scales following residue sprays are not understood, but the fungicidal activity of the material is probably of importance.

Whether the zinc sulfate or the lime is the fungicidal factor in the zinc-lime mixture is yet to be determined. It is possible that other forms of zinc might interfere less with insect control. In view of the present nutritional knowledge, zinc sprays are necessary for proper tree vigor. Copper is also necessary from a nutritional standpoint as well as for the control of melanose, *Diaporthe citri* (Faw.) Wolf, which adversely affects the external quality of the fruit. This discussion is not intended to discourage the use of these sprays, but it is anticipated that further investigations may yield results which will indicate which chemical form of these materials interferes least with insect control and whether or not the timing of sprays can be so altered as to minimize the deleterious effects.

EFFECTS ON RUST MITES AND OTHER CITRUS INSECTS.—Rust mite counts were made on leaves and fruit at intervals throughout the experimental period and all plots developed heavy rust mite populations. In the Pineapple oranges rust mites increased somewhat more slowly on the trees which did not receive zinc-lime or copper. Similar trends were not evident in the Valencia orange experiment. Table 2 presents the results of samples taken in the packing house from the Pineapple orange experiment. The plots which were not sprayed with copper or zinc-lime had the highest number of fruit with no rust mite injury and the least with late rust mite injury. The collection of these data did not allow for the recording of both late and early injury on an individual fruit. Where both were present, only late injury was checked. Thus, in the copper and zinc-lime plots, there appears to be a lower incidence of early rust mite injury. Actually, early injury was as common as elsewhere, but the late injury was much more prevalent and only this was recorded. The increased incidence of late injury would appear to substantiate the tendencies noted in the rust mite counts mentioned above. No accurate check was kept on the intensity of rust mite injury, but general notes made during the course of the packing house operation showed that the fruit on trees where copper sprays had been applied was the most severely injured. The two applications of wettable sulfur on the one treatment did not appear to reduce either the number of rust mites found at a later date or the amount of injury noted on the fruit.

The data presented above again conform to the Yothers & Mason (1930) report and to field observations on rust mite incidence and injury. Thus, where copper or zinc or both are sprayed, rust mite control is more difficult than where these are omitted from spray schedules. Fisher *et al.* (1949) have reported a fungus disease of rust mites and this would suggest that the increased rust mite injury on the copper and zinc sprayed plots was partially attributable to fungicidal activity.

Observations were made on populations of citrus red mite and Florida red scale, but no conclusions could be drawn.

SUMMARY AND CONCLUSION.—Orange trees were sprayed twice with each of five materials (pyrophyllite, wettable sulfur, copper plus pyrophyllite, zinc sulfate plus lime plus pyrophyllite, and zinc plus lime plus copper). These treatments were all applied at 6.0 pounds of spray material per 100 gallons of spray and they were compared with unsprayed controls. Trees sprayed with mixtures containing copper or zinc lime or both had more prolonged periods of high purple scale populations than with the other treatments. There was less increase of scales on the unsprayed controls than on the sprayed plots. The presence of any of these materials as residues appeared to result in increased scale populations, but wettable sulfur and pyrophyllite sprayed trees had population decreases in July at the same time as the unsprayed controls. On the zinc-lime or copper plots, scale populations showed no decrease until September, and even then more scales were present than on the other treatments. The advent and intensity of chytridiosis incidence was a factor in scale population decreases, but data obtained here seemed to indicate that other unknown factors were also in operation.

There was some evidence to show that rust mite populations also were more severe following the use of copper or zinc-lime sprays.

It was concluded that any of the materials used resulted in increases in purple scales which were greater than would occur on unsprayed trees and that where amounts of residue are similar, the chemical nature of the residue is the determining factor in the extent of the duration of the abnormally high populations.

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RETIREMENTS FROM BEPQ

George F. Moznette who has been in charge of the Bureau's pecan insect laboratory at Albany, Georgia, retired as of January 1, 1949, after more than 30 years of service.

Charles T. Greene retired from the Division of Insect Identification of the Bureau of Entomology and Plant Quarantine on March 31, 1949. Mr. Greene was engaged as a specialist in taxonomy of Diptera.

Mr. Carl Heinrich retired from the Division of Insect Identification of the Bureau of Entomology and Plant Quarantine as of June 30, 1949. Mr. Heinrich was head of the Section of Lepidoptera and was a specialist in taxonomy of Lepidoptera with emphasis on the Pyralidoidea and immature stages. Mr. Heinrich is continuing work on a part-time basis in order to complete a monumental paper dealing with the classification of the Phycitidae. This paper, which is nearing completion, will consist of approximately 1,500 manuscript pages and 300 plates and will treat approximately 750 species.

S. S. Crossman, who has been for many years engaged in the control of the gypsy moth in the Division of Gypsy and Brown-Tail Moths Control of the Bureau of Entomology and Plant Quarantine, where he served as assistant division leader, retired on June 30 after more than 30 years of service. He has been succeeded as assistant division leader by Mr. Harry L. Blaisdell who has also had 39 years of service.

The Division of Gypsy and Brown-Tail Moth Control of the Bureau has announced the retirement of Clifford E. Hood after over 36 years of service; of Reginald Wooldridge with 41 years of service; of Henry N. Bean after 40 years of service; Frank N. Bancroft after more than 33 years of service; of Saul Phillips after more than 30 years of service, and Orren C. Otis after 35 years of service.

SCIENTIFIC NOTES

Collection of a Fourth Instar Larva of *Anopheles albimanus* at Boca Raton Field in 1944

STANLEY J. CARPENTER[1]

While the writer was serving as Chief of the Entomology Section of the 4th Service Command Medical Laboratory at Fort McPherson, Georgia a 4th instar larva of *Anopheles albimanus* Wied. was collected from a canal at Boca Raton Field, Florida on May 16, 1944. The specimen was identified by Capt. E. R. Tinkham, Entomologist, and his assistants at Boca Raton and forwarded to the writer for confirmation. This specimen has been briefly referred to in previous reports by Carpenter (1945a, b) and Mulrennan *et al.* (1945). Pritchard *et al.* (1946) have recently reported the finding of a 4th instar larva of *A. albimanus* on Big Pine Key situated at the northern end of the lower Florida Keys.

Prior to the discovery of this larval specimen of *Anophelos albimanus* a well organized mosquito survey and control program had been set up at Boca Raton by Capt. Tinkham and his associates. This program provided for weekly larval and adult mosquito collections from carefully selected stations; New Jersey light trap collections each night; and frequent night-time biting collections. The discovery of this single specimen of *A. albimanus* is an indication of the thorough manner in which this work was performed.

During the week of May 15 to 20 when the larva of *Anopheles albimanus* was collected, a total of 2295 dips for larvae was taken at Boca Raton Field. 125 dips were taken at larval station No. 9, where *A. albimanus* was collected. This station yielded two larvae, one *A. quadrimatulatus* and one *A. albimanus*. Larval station No. 9 consisted of a section of a canal approximately 300 yards in length and situated between two bridges. This area of the canal was rather shallow, had very little flow and a considerable portion of the water surface was matted with vegetation. The breeding site was located about 300 yards from the flight strip where airplanes were usually unloaded.

During the week (May 22 to 27, 1944) following the discovery of *Anopheles albimanus*, the search for larvae was intensified in the canals, and 6010 dips were taken. A total of 2150 dips were taken at station No. 9 and three larval specimens were found, two *A. quadrimaculatus* and one *A. crucians*. Mosquito collections, on a weekly basis, were continued by Army personnel at Boca Raton Field throughout the remainder of 1944 and 1945 and no additional specimens of *A. albimanus* were found.

Immediately after the discovery of *Anopheles albimanus* breeding in Florida the writer was requested by the Surgeon of the Fourth Service Command to proceed to Boca Raton and direct a search for additional specimens. During the week (May 28 to June 3, 1944), an intensive search was made for larval and adult mosquito specimens by the writer, Capt. Tinkham and his assistants; and Mr. Edwin L. Seabrook representing the U. S. Public Health Service.

During the investigation of this problem the writer contacted the Operations Officer at Boca Raton Field and obtained information that only three planes had arrived at the field from outside the United States during a three month period, March to June, 1944. Two of these planes arrived from Nassau on April 24 and May 2 and the third plane arrived from Puerto Rico on May 1. All three planes stopped at Morrison Field at West Palm Beach, Florida en route to Boca Raton. *Anopheles albimanus* is an important vector in malaria in Puerto Rico and the plane coming from Puerto Rico arrived just 16 days prior to the finding of the fourth instar larval specimen. Records of arrival and freeing of planes from insects clearing through Morrison Field after coming from outside the country were kept in the office of the landing service officer at Morrison Field. These records showed that the plane coming from Puerto Rico had cleared through Morrison Field before proceeding to Boca Raton but there was no information to show that it had been given the routine disinsectization treatment.

After the investigation was completed at Boca Raton Field all canals within one miled of the flight strip were treated each week with paris green dust during the remainder of the summer by Army personnel. The Palm Beach County Mosquito Control Association immediately began weekly oiling of canals adjacent to but outside the limits of the air field.

DISCUSSION.—Information obtained by the writer during a visit to Boca Raton and Morrison Fields, following the finding of a 4th instar larval specimen of *Anopheles albimanus* at Boca Raton during May, 1944, indicates that the plane arriving from Puerto Rico on May 1, 1944 was not treated for insect control upon arrival at West Palm Beach.

It is believed that the larva of *Anopheles albimanus* was among the progeny of a female carried to Boca Raton by airplane. Since no additional specimens have been found in the vicinity it is assumed that it failed to establish itself in the area; however, this fact cannot be definitely established without additional entomological surveillance during the next few years. The specimen has been deposited in the United States National Museum.

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The Spermatozoon as a Diagnostic Tool in Mealybug Taxonomy

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Spermatozoa taken from several species of *Pseudococcus* show differences so striking as to suggest their usefulness in the taxonomy of this genus. Furthermore, a study of spermatozoa may be of value in distinguishing the several physiologically distinct, but as yet morphologically inseparable, forms comprising the *Pseudococcus maritimus* (Ehrhorn) complex. It is also possible that phylogenetic relationships may be revealed through a comparative study of spermatozoa.

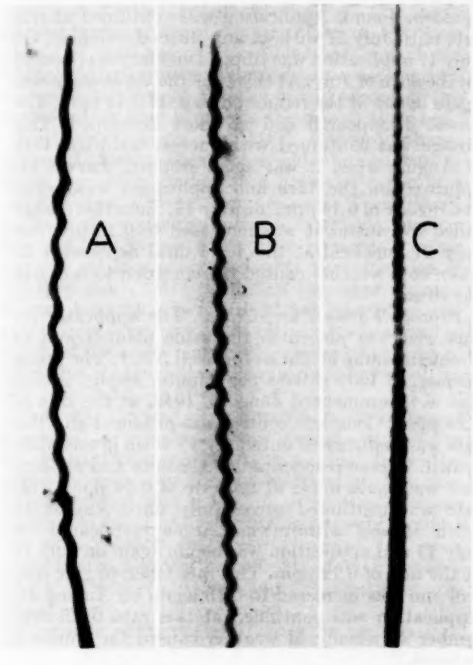

FIG. 1.—Heads of mealybug spermatozoa. A, *Pseudococcus sequoiae*. B, *P. citri*. C, *P. maritimus*.

Apparently the spermatozoa of the genus *Pseudococcus* possess a basic organization which exhibits differences at the species level. The morphological formula of such a spermatozoon seems to be a spiral or auger shaped head followed by a long cylindrical, flagellate tail composed of a cytoplasmic envelope surrounding a group of interwoven fibrils. The tail terminates in a slender filament, the endpiece.

Examinations of spermatozoa have indicated that differences between species of *Pseudococcus* are most readily seen in the various forms of the heads and endpieces. The accompanying photomicrographs demonstrate the characteristic sperm heads of three species. Figure 1A is the head of *Pseudococcus sequoiae* (Coleman), figure 1B is the head of *P. citri* (Risso), and figure 1C is the spiral head found in *P. maritimus* (Ehrhorn). The endpieces of these three species differ appreciably, and in combination with the illustrated heads, seem to offer good taxonomic characters. The tails of *P. sequoiae* and *P. maritimus* taper, more or less gradually, into the filamentous endpieces. The tail of *P. citri*, however, is abruptly rounded posteriorly, and the endpiece appears as a very short, fine filament protruding from this blunt termination.

The relative lengths and widths of the spermatozoa may also prove of some taxonomic value.

The technique for examining the discussed spermatozoa is rapid and relatively simple. The spermatozoa are dissected from the male mealybugs in a drop of distilled water on a glass slide, and the water droplet is permitted to dry. After drying the preparation is stained with methyl alcohol and giemsa blood stain for 2 minutes and rinsed in distilled water. When viewed under an oil immersion lens the structures described herein are readily distinguishable.

Control of *Aëdes* Mosquitoes by Direct Introduction of DDT into Irrigation Waters

GORDON F. SMITH,[1,2] and A. F. GEIB, *Bakersfield, Calif.*

During the 1946 and 1947 mosquito breeding seasons an attempt was made in the Kern Mosquito Abatement District to control *Aëdes dorsalis* and *A. nigromaculis* in irrigation flooded fields and pastures by the direct introduction of DDT emulsible concentrate into the irrigation waters before they entered the fields. In the course of this period equipment was developed from the rather crude beginning of a five gallon can with a nail hole in the bottom, the flow regulated with a match stick, to a 50 gallon siphon drum with a metering tip suspended directly in the irrigation stream.

This earlier work was written up in the form of a preliminary report (Geib & Smith 1949).

During the season of 1948 further study was carried on with this type of application on two ranches in the vicinity of Bakersfield.

One of these ranches covers 557 acres. The primary crop is alfalfa, with the exception of a small cattle pasture of about 40 acres. The water used on this ranch comes entirely from two deep wells designated No. 1 and No. 2. Well No. 1 has a flow of 1800 gallons per minute and Well No. 2 has a flow of 1000 gallons per minute. These pumps may operate independently or flow into a common irrigation line, depending on the amount of water required.

This ranch is located approximately 15 miles southwest of Bakersfield. The land is poorly leveled with innumerable low spots scattered irregularly over the fields. The soil is highly alkaline and very tight, holding irrigation waters on the surface for long periods of time. The pH of the water at the pump is 7.0 but may be 7.4 at the low ends of the fields. Since the water in these depressions is normally hidden by the vegetation and difficult to locate, it has been necessary to spend two man days a week to obtain satisfactory mosquito control.

Pacific Slope Branch Program, 1949.

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[2] Manager, Kern Mosquito Abatement District, Bakersfield.

The other test area was a portion of the Stockdale Ranch of the Kern County Land Company. This area, approximately 200 acres, was irrigated from a single well. The upper end of the field is sandy and water penetrates rapidly. However, the lower end, though not highly alkaline, is tight soil and the water may be retained in the lower portions of this section for considerable periods of time with a resultant heavy breeding of flood water *Aëdes*. The well furnishing water for this field pumps 2000 gallons per minute.

When this work was initiated in 1946 the Kern Mosquito Abatement District was using a 25 per cent DDT emulsible concentrate purchased from the War Assets Administration. Since the formula of the emulsible concentrates used by the Armed Services varied, the makeup of the particular material used is not known. It was an extremely stable emulsion of very fine particle size and dispersed itself rapidly in water without agitation. The particles remained in suspension almost indefinitely without any evidence of creaming off at the surface or settling out at the bottom.

When this material was no longer available various proprietary emulsible concentrates were tried. All of these materials were unsatisfactory. For the most part they were not sufficiently stable for this use. Those that did not break either rose to the surface or settled to the bottom and would not remain evenly dispersed in the drum. The emulsifier in one of the materials tested reacted with the minerals in the alkali water to form a hard soap curd.

Since difficulties were encountered by mosquito abatement agencies throughout California in using the DDT emulsible concentrates available on the market, new formulations were made up by several local manufacturers for use in mosquito control. Only two of a number of preparations submitted for trial were deemed to have the physical characteristics adequate for use in this manner. These emulsions were extremely stable in all types of water tested and would remain evenly dispersed for several days. One of these materials was used in all 1948 tests.

Due to the nature of the type of application the physical characteristics of the material used will influence greatly the success or failure of the treatment. Since the emulsion must remain in the drum for the period of time set to empty it, periods of 24 hours or more, it must be very stable in order that the treatment will be as uniform as possible over the entire period of application. It should disperse readily in the water and have a dispersed stability of not less than 36 to 48 hours when the siphons are to be refilled daily. Since the amount of material used is minute relative to the quantity of irrigation water the particle size of the emulsion should be extremely fine in order that the toxic agent may be dispersed as thoroughly as possible to allow for maximum contact with the mosquito larvae. Emulsions commonly used for orchard and other crop spraying are too coarse and unstable for this work and special formulations are required. Two of the DDT formulations evolved for mosquito control in California are considered to be satisfactory by the authors.

The equipment used in these tests has already been described (Geib & Smith 1949). It has not been modified. This equipment seems to be as simple and as sturdy as possible. The glass metering tip may be replaced by a metal one. However, at least in this area, allowance must be made for varying the size of the orifice as the drums may be located anywhere from 18 inches to 12 feet above the surface.

The containers used in these tests were ordinary 55 gallon steel drums with the heads of each cut out and covered with a piece of canvas. The metering device was set to empty in about 26 hours. Since rust particles from the drum are large enough to easily plug the tip, it should be washed out each time they are refilled. The hoses should also be checked from time to time and replaced as needed since even the synthetic materials tried have broken down under continuous use.

RESULTS.—*Peacock Farms Well No. 1.* The dispenser for this well was placed on top of a standpipe at the outlet of the pump discharge and about 10 feet above the water surface. The well pumped 1800 gallons per minute. Application was started the 25th of June, 1948, DDT being introduced to the irrigation water at the rate of 0.23 ppm. *Aëdes dorsalis* larvae were present in the field at this time. Immediately after beginning application no new larvae could be found. Application was continued at this rate until July 17 without any *Aëdes* developing. On July 17 application was stopped and larvae appeared on the 20th of July. At this time the application was again begun at the reduced dosage of 0.15 ppm. The larvae disappeared and no more developed. This dosage was continued with success until the 11th of August when it was again stopped. Larvae reappeared on the 15th and application was begun at a dosage of 0.14 ppm. on July 17. Since this dosage failed to control, it was increased to 0.15 ppm. on July 21 and held at this level until September 22 when cold weather caused the emulsion to break in the drum.

Peacock Farms Pump No. 2. The applicator for this well was placed in the same manner and at about the same height as for Well No. 1. The pump discharged 1000 gallons per minute. Application at this well commenced June 25, 1948, at the rate of 0.24 ppm. Complete control was obtained and this rate was maintained until July 17 when it was withdrawn. Larvae reappeared on the 20th and application was again made at the rate of 0.16 ppm. This rate was continued successfully until August 12 when it was withdrawn. Larvae reappeared on July 17 and application was begun again on July 18 at the rate of 0.12 ppm. This rate failed to give control and was increased to 0.16 again on August 21. Application was continued at this rate until September 22 when cold weather caused the emulsion to break.

Stockdale Ranch Pump No. 6F54. Application was made on this pump from September 1 to 22, 1948, at the rate of 0.14 ppm with complete success.

CONCLUSIONS.—The direct introduction of suitable DDT emulsible concentrates into irrigation waters for the control of *Aëdes dorsalis* and *A. nigromaculis* by a siphon system is feasible for practical use.

Complete control was obtained on two ranches in the Kern Mosquito Abatement District by this method at a dosage rate of approximately 0.15 ppm. As indicated by the rapid reappearance of larvae when treatment is stopped no residual action is obtained at the low dosages used.

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An Attempt to Protect Cattle from Grub Infestation by Use of Insecticides

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In the vicinity of Kerrville, Tex., an attempt was made in 1948 to protect cattle from infestation by *Hypoderma lineatum* (De Vill.), the common cattle grub. The cattle were sprayed every 2 weeks from January 1 to April 28 with high concentrations of six chlorinated hydrocarbon insecticides. Preliminary laboratory work by W. L. Barrett, Jr., and R. W. Wells (unpublished report) had indicated that treatment with 1.5 per cent suspensions of toxaphene, chlordan, benzene hexachloride, and gamma benzene hexachloride prevented the eggs of *H. lineatum* from hatching. It was also known that these insecticides are highly toxic to the newly hatched larvae of many dipterous insects. For these reasons it was thought possible that one of the chlorinated hydrocarbon insecticides possessing good residual action might kill the young larvae of this species before they penetrate the skin of their host.

Wettable powders of DDT, dichlorodiphenyl dichloroethane, methoxychlor, chlordan, and toxaphene were each applied to a group of cattle at a concentration of 2 per cent. Benzene hexachloride was used at a concentration of 0.24 per cent gamma isomer plus 1.76 per cent other isomers. Another group of cattle was sprayed with a combination of 0.75 per cent DDT and 0.03 per cent gamma benzene hexachloride plus 0.22 per cent other isomers. These seven groups of cattle were pastured in four localities and a comparable group of unsprayed cattle was designated as an untreated control for each locality.

The insecticides were applied with a power sprayer at a pressure of 300 pounds per square inch. Special care was taken to see that the entire surface of each cow's body was wet to the skin and an average of 5 gallons of spray material per animal was used. All the materials were applied nine times except chlordan. Three of ten cows sprayed with chlordan died after the fourth application (Bushland *et al.* 1948) and this treatment was discontinued.

The cattle were sprayed during the first week of January and once every 2 weeks thereafter until April 28. This is the period when the adult flies are active in the Kerrville area. It is known that small numbers of adults occur at other times of the year, but all the grubs that appeared in the backs of the cattle either unusually early or late were ignored when making infestation counts in the fall.

Preliminary results of this test were obtained on May 4 when one animal from each sprayed group was sacrificed for toxicological studies. At this time, first-instar larvae were found in the gullets of all the treated animals except the cow that had been sprayed with 0.24 per cent gamma benzene hexachloride plus 1.76 per cent other isomers.

Beginning on October 1 the cattle were examined at monthly intervals and the grubs in the backs were removed and counted. The results are shown in table 1. None of the insecticides completely protected cattle from infestation, and most of the sprayed groups had about as many grubs as the unsprayed groups. No attempt was made to determine the difference that would be significant statistically, but it is known that small differences are not significant. For instance, the number of grubs counted in individual cows in the unsprayed group at locality A ranged from 3 to 200.

Table 1.—Average number of grubs found in cattle sprayed with insecticides during the preceding heel fly season.

Locality	Treatment[1]	Number of Cattle	Average Number of Grubs Removed per Animals[2]
A	Chlordan 2%	7	12.2
	Toxaphene 2%	9	23.1
	Gamma Benzene Hexachloride 0.24%+1.76% other isomers	8	5.3
	Untreated Checks	10	39.9
B	DDT 2%	10	8.6
	Methoxychlor 2%	11	11.6
	Untreated Checks	8	6.0
C	DDT 0.75% plus Gamma Benzene Hexachloride 0.03%	15	11.7
	Untreated Checks	9	9.8
D	TDE 2%	16	3.1
	Untreated Checks	15	6.9

[1] Insecticides were applied at 2-week intervals beginning January 2, 1948. Chlordan was sprayed only four times; the other materials nine times.

[2] Counts are based on the number of grubs found during the period October 1 to January 14, 1949.

In comparison with the average number of grubs in untreated animals, the 0.24 per cent gamma benzene hexachloride treatment appears to have reduced the infestation considerably. However, the concentration of benzene hexachloride used in the treatment was high, and there is very little hope that this material would be of any practical value for grub control if it were applied at safe concentrations only two or three times during the season of adult activity.

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Grasshopper Population Reduced by Gulls

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The importance of gulls as predators on Mormon crickets received early and prominent recognition by the first Mormon settlers in Utah. Henderson (1931) gives several excerpts from these early accounts of gulls feeding on crickets, and describes the present-day prevalence of gulls around Great Salt Lake and their habit of following farm machinery to destroy grasshoppers, other insects, and small rodents. However, very little has been recorded as to the actual effectiveness of gulls in reducing insect populations. Bradshaw (1934) gives an account of an enormous flock of Franklin's gulls in Canada feeding on grasshoppers, but does not give an appraisal of the reduction in grasshopper population. Cottam (1934) recorded the feeding of California

gulls on a species of large midge (chironomid) in Utah, with a reduction in midge population of "fully 95 per cent" where feeding occurred. Cottam (1944) also records damage to crops by gulls in various parts of the United States.

In the course of ecological studies of grasshoppers in north central Montana in 1948, gulls were observed feeding on grasshoppers. These observations were made on a 160-acre field situated on the east side of the Cut Bank-Valier county road about 15 miles south of Cut Bank, Montana. The field contained alternate strips of barley and fallow ground 175 feet wide extending north and south for one-half mile. The grasshopper population was composed almost entirely of the two-striped grasshopper, *Melanoplus bivittatus* (Say), which measured 1 to 1.75 inches in length.

Population densities were based on visual estimates made in the manner suggested by Shotwell (1935). During July the grasshopper population was approximately 25 per square yard in the grain. During the day some of the grasshoppers would move from the grain to the fallow strips, presumably for the extra warmth or the sunshine. A considerable amount of foliage was being consumed by this population, but no apparent injury to the grain was taking place. By late July clipping of the heads had started. This injury was caused by the grasshoppers chewing on the grain stems just below the heads, causing the heads to drop to the ground or break over and dry.

On August 3 an estimated 1000 gulls were observed on a temporary pond at the north end of the field. This was the first time gulls had been seen in this locality. The species was not determined definitely, but it is believed to have been the California gull, *Larus californicus*. At 4 P.M. at least half of the flock left the pond and flew to the north end of the fallow strip adjacent to the road. From here the flock moved, by hopping and short flights, down the entire half-mile length of the fallow strip in about 5 minutes. On reaching the south end of the field they flew back to the pond.

An examination of the fallow strip immediately afterward showed grasshoppers to be very scarce. The next two fallow strips were found to have about five grasshoppers per square yard, which was the probable population of the first strip before the gulls appeared. Toward the end of the examination of the third fallow strip the gulls were seen leaving the pond and starting to feed in this strip. The writer stepped back in the grain about 2 feet and watched a repetition of the previous feeding at close range. After this feeding the population had been reduced to approximately one grasshopper per square yard. Furthermore, the remaining population was composed almost entirely of males, the large, gravid, slow-moving females having been almost completely annihilated. Three *Melanoplus bivittatus* females in the process of egg deposition, which had been spotted so that the egg pods could be collected, were gone when the gulls passed. Two of them had laid only a few eggs, while the third had deposited about half the usual number. On reaching the end of the field the gulls again flew back to the pond.

On the following day the number of gulls visiting the field increased to approximately 2500, and on August 5 to 5000. On August 6 they decreased to 2500, and on August 7 to 1000. After this only a few gulls were seen intermittently. Movements of gulls down the fallow strips were never so well defined as on the first day. Often they would work part way down a strip and then fly to some other area in the field, or to another field. Gulls were never seen alighting in the grain, or even walking into it from the fallow. All feeding was done on the fallow land. A cursory examination of gull excrement showed it to be composed almost entirely of grasshopper fragments.

Grasshopper population was estimated again on August 7. Only five grasshoppers per square yard were found in the grain as compared with 25 per square yard before the gulls arrived, while in the fallow there was one or less per square yard. This was a reduction of 80 per cent in 5 days. Such a rapid and thorough decrease was believed responsible for saving this field, as well as several others in the immediate vicinity. Gulls cannot be relied upon to control grasshoppers, but when present they are efficient predators.

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New Materials for Control of Strawberry Crown Borer

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Widespread injury by the strawberry crown borer during the late summer of 1948 in the Jackson Purchase and Jefferson County berry growing areas of Kentucky prompted further studies on possible control measures. Since growers had made little use of methyl bromide fumigation or poison baits, control methods worked out in 1940–44 (Ritcher 1944), attention was turned to the newer insecticides.

In early April of 1949, several hundred overwintering crown borer adults were collected by W. D. Armstrong, and the writer, from a borer-ruined strawberry patch near Sharpe, Kentucky, where a few plants remained alive after discing. From 2 to 13 adults were found on or about each plant. These adults were taken to Lexington, where laboratory tests were made with a number of the newer organic insecticides. In each case 4 potted strawberry plants were dusted evenly with each material, using a hand duster. Ten crown borer adults were then placed at the base of each plant and confined by means of a cylindrical, 16 mesh, galvanized wire cage placed over the plant.

Results of several laboratory tests are summarized in table 1. Of the materials tested 1 and 2 per cent parathion dust, 5 per cent chlordan dust and 20 per cent toxaphene dust gave excellent control.

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

Poor results were obtained with benzene hexachloride (odorless) dusts containing 1.5 per cent and 3 per cent of the gamma isomer and 5 per cent DDT dust. Fair results were obtained with DDT spray (1 pound actual) and a dust containing 2.5 per cent of an experimental material.[2]

Parathion was the quickest acting of the materials tested, killing most of the crown borer adults in 3 days time. Where chlordan and toxaphene were used many affected beetles continued to move their appendages for 5 to 6 days but none recovered. Beetles affected by benzene hexachloride, however, often recovered and proceeded to feed normally.

FIELD TEST.—On April 20 a newly set strawberry patch was located in Jefferson county which was being invaded by crown borer adults from adjacent old patches, one of which had been plowed under several months previously. Two plots each 140 feet long and 4 rows wide were dusted, one with 5 per cent chlordan dust and one with 20 per cent toxaphene dust, using a knapsack, puff type duster. The rest of the patch was left untreated.

Table 1.—Laboratory tests of newer organic insecticides for control of the strawberry crown borer.

TREATMENT	PER CENT ALIVE	PER CENT MORIBUND OR DEAD	FEEDING PLACES
April 9 Tests			
2% Parathion	0	100	15
1.5% gamma Benzenehexachloride (odorless)	34.5	65.5	9
20% Toxaphene	3.1	96.9	10
5% Chlordan	0	100	4
Check	97.4	2.6	Many
April 14 Tests			
2% Parathion	0	100	9
1.5% gamma Benzenehexachloride (odorless)	89.7	10.3	13
20% Toxaphene	0	100	25
5% Chlordan	0	100	4
5% DDT	67.6	32.4	30
DDT (1 pound actual) per 100 gallon	34.2	65.8	47
Check	100	0	Many
April 27 Tests			
1% Parathion	0	100	
2.5% Compound 118	23.7	76.3	
3% gamma Benzenehexachloride (odorless)	69.4	30.6	
Check	94.7	4.3	

Five days later, on April 25, dead and dying crown borer adults were fairly common about treated plants especially on the side of the new patch closest to the old patches. Some beetles were lying beneath the leaves near the crowns of the plants; others were in depressions in the soil surface, in some cases out in the open a foot or more away from plants. In all, 1 live, 13 moribund, and 40 dead crown borer adults were collected from the toxaphene plot and 1 live, 21 moribund, and 31 dead crown borer adults from the chlordan plot. Many live beetles were still present in the untreated area.

DISCUSSION.—These tests indicate that several of the newer insecticides can be used to kill adult crown borers. Since new patches usually become infested by adults crawling from nearby old patches, the best method of control would appear to be one thorough treatment of all old patches early in the spring, followed by repeated treatments of new patches, at least on the borders closest to an old patch or other sources of infestation such as cinquefoil. Treatment of new patches would require the use of very little material since only a puff of dust is needed per plant.

SUMMARY.—One and 2 per cent parathion dust, 5 per cent chlordan dust and 20 per cent toxaphene dust all gave excellent control of strawberry crown borer adults in laboratory tests. Five per cent chlordan and 20 per cent toxaphene were tried in the field and gave similar results. Early spring treatment of old strawberry patches and repeated treatment of border rows in newly set patches are suggested as means of controlling crown borer by killing adults before egg-laying occurs.

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[2] *Compound 118.*

Acaricidal Properties of Hexachlorophenol

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It has been established by Steiner (1944), Hough (1946), DeBach (1947) and others, that the use of DDT in apple orchards creates acute problems in controlling summer European red mites, *Parate tranychus pilosus*. In view of this adverse phenomenon, the finding of new acaricides becomes of immediate importance. While conducting toxicological tests with various synthetic organic compounds, the writer found the following chemicals to be toxic to spidermites, *Tetranychus bimaculatus*, on greenhouse plants.

Hexachlorophenol, C_6OCl_6
Thioacetanalide, $C_6H_5NHCSCH_3$
Thymol, $CH_3C_3H_7C_6H_2(OH)$
P-Chlorothymol, $CH_3C_3H_7C_6H_2(OH)Cl$
Diphenyl-O-chlorophenyl phosphate, $ClC_6H_4O(C_2H_5O)_2PO$

Of this group, hexachlorphenol ranked highest in toxicity and was, therefore, tested further on European red mite.

MATERIALS AND METHODS.—Hexachlorophenol is a dull yellow crystalline compound, insoluble in water but soluble in organic solvents, such as alcohols, acetone, benzene and petroleum distillates. It melts at 106° C. and its sp. gr. is 0.779.

The chemical was tested as a water suspension. For this purpose 25 per cent hexachlorophenol, 2.5 per cent sodium lauryl sulfate (Commercial grade) and 72.5 per cent of Clay[2] were mixed in the order

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, The State University of New Jersey, Department of Entomology.
[2] *Attaclay.*

listed and ground by pestle and mortar to homogeneous consistency. The resultant dust was readily dispersible in water. Concentrations ranging from 1 pound down to 0.5 ounce of actual hexachlorophenol per 100 gallons of water were tested in the laboratory on apple twigs infested with European red mites. The twigs were immersed in the spray mixtures, momentarily removed and placed in bottles of water. By this procedure the leaves were thoroughly wetted with the toxicant. Counts of dead and live mites (nymphs and adults) were made after 24 hours. The tests were repeated three times and the averages are given in table 1. The formula worked out by Abbott (1925) was used for computing the effectiveness of the insecticide.

A preliminary, small scale field test was also made. For this purpose, branches of Red Delicious apple trees, requiring about two gallons for coverage were sprayed by hand bucket pump. The trees were selected in a partly abandoned orchard, heavily infested with European red mites. Four concentrations, varying from one to eight ounces per 100 gallons, were tested. Observations were made two days after application.

Table 1.—Laboratory tests with hexachlorophenol on European red mites, on apple foliage.

Pounds of Toxicant per 100 Gals.	Dilution of Toxicant	Total Mites Counted	Per Cent Dead Mites After 24 Hours
1 lb.	800	251	100
8 oz.	1,600	321	100
4 oz.	3,200	258	97
2 oz.	6,400	339	93
1 oz.	12,800	303	91
0.5 oz.	25,600	251	75
Check	none	193	27
Blank	none	163	22

Results.—The data from the laboratory tests in table 1 indicate 91 to 100 per cent mortality in concentrations ranging from one to eight ounces of toxicant per 100 gallons of water. The lowest concentration tested, 0.5 ounce per 100 gallons, produced 75 per cent dead mites.

Observations on the field tests have shown the following range of control with different spray concentrations, based on ounces of hexachlorophenol per 100 gallons of spray; 100 per cent control with either 4 or 8 ounces; 94 per cent with 2 ounces; and 86 per cent with 1 ounce.

No foliage injury was observed either in the laboratory or in the field. A separate test on plant tolerance to the hexachlorophenol, applied by hand-pump sprayer, on apple and peach trees, has disclosed no injury in concentrations of eight ounces or lower per 100 gallons of spray. On bean foliage, grown in the greenhouse, injury was noted from spray concentrations of two ounces or higher, but none from one ounce per 100 gallons of spray.

Summary and Conclusions.—Preliminary tests with hexachlorophenol were conducted on European red mite, *Paratetranychus pilosus*, infesting apple foliage. The results indicate high toxicity both in the laboratory and in small-scale field tests.

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Control of the Omnivorous Leaf Tier on Flax

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The omnivorous leaf tier, *Cnephasia longana* (Haworth), has recently been reported from California[1] where it does considerable damage to flax and cut flowers. During the 1949 season it has also been found feeding on strawberries in this state.

The overwintering first instar larvae were first found this year on February 19 on the bark of oak trees. They were just emerging from their winter quarters and spinning the webs on which to float to their host plants. Two days later they had started to mine the leaves of native weeds. Subsequent to this date, for a period of about 6 weeks, numerous larvae were constantly emerging from the bark of oak, eucalyptus, and cottonwood trees. Peak emergence occurred during the week of March 21 to 28.

The young larvae began mining the leaves of flax as soon as the cotyledons broke through the ground. After spending the first instar as leaf miners, many of the larvae left the mines and began to feed and web the terminal growth of flax; however, a few second instar larvae could occasionally be found in their mines.

The average infestation in the Palo Alto area during 1949 was much more severe than in 1948. Many areas close to trees showed infestations between 90 and 100 per cent. The flax in the Pescadero area, which is in a cooler, coastal region, was considerably later than that around Palo Alto and as a result it escaped being infested.

During the season the known range of this species has been extended to the east side of south San Francisco Bay and as far south as Santa Cruz where it has been reported as injuring strawberries.

For the second year, numerous larvae of all ages were brought into the laboratory for rearing in an attempt to find parasites of this insect, but none was found. Larval parasitism has been reported to be quite common in the northwest, but if present in California it is as yet quite low.

For pupal chambers the insects webbed together blades of grass, leaves, and stems of vetch, or rarely several contiguous flax stems. On the broad-leaved plants such as dock, they sometimes folded a single leaf.

On emergence there was a tendency to push out the pupal skin as shown in fig. 1. Adults were found in the field during the first week in May and by the end of the second week were extremely abundant.

Investigations on the control of this insect on flax were instituted during the past season.

[1] Middlekauff, Woodrow W. 1949. The omnivorous leaf tier in California. Jour. Econ. Ent. 42 (1): 35–36.

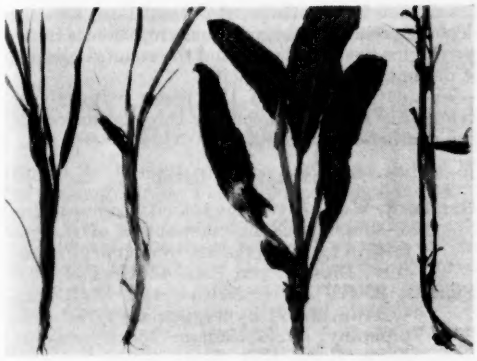

FIG. 1.—Pupal skins of *Cnephasia longana* (Haw.) showing location and construction of pupal nest. natural size.

The following materials were used in the control studies: 15 per cent wettable parathion; 50 per cent wettable DDT; 50 per cent wettable dichlorodiphenyl dichloroethane and benzene hexachloride, containing 10 per cent gamma isomer.

These materials were applied to .01-acre blocks in duplicate by means of a 3-gallon knapsack sprayer.

For population counts, from 25 to 100 infested tips were carefully examined from each plot for the presence of larvae to determine the efficacy of the various treatments. The plots were sampled on the third and tenth days following treatment.

Treatment data are summarized and presented in table 1.

The insecticides were applied on April 12 and 13 when the flax was about 6 to 10 inches in height. At this time the larvae had distinctly webbed the terminal growth which greatly increased the difficulty of contacting them with the insecticides. As shown in the table, DDT and dichlorodiphenyl dichloroethane used at the rate of 2 pounds of 50 per cent material to the acre gave the best results, with DDT being somewhat superior. Benzene hexachloride containing 10 per cent gamma isomer and applied at the rate of 10 pounds per acre gave poor control, while fifteen per cent parathion at the rate of 1 and 1.5 pounds per acre proved to be ineffective.

The plots were examined on April 30 at the peak of bloom. The flax in the DDT and DDD plots was in full blossom while not a single blossom could be noticed in the checks nor the parathion treated plots. In the benzene hexachloride plots about one-third of the plants were in bloom.

It is felt that much better control would have been obtained with DDT and dichlorodiphenyl dichloroethane if these had been applied about 10–15 days earlier. This would have more closely coincided with the larval migration from the mines to the terminal growth. Many larvae would thus have been killed before the tips of the plants were webbed.

The Effect of Four Commonly Used Synergists on a Synthetic Pyrethroid

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Schechter *et al.* (1949) have synthetized a product similar to one of the natural pyrethrins and known chemically as dl-2-allyl-4-hydroxy-3-methyl-2-cyclopenten-1-one ester of dl-cistrans-chrysanthemum monocarboxylic acid. This compound is referred to as a synthetic pyrethroid in this paper.

Table 1.—Treatments, rate of application, and control obtained with several insecticides against larvae of the omnivorous leaf tier on flax.[1]

TREATMENT	RATE/ ACRE IN POUNDS	POST TREATMENT SURVEYS								CONDITION OF BLOOM APRIL 30
		16 April				20 April				
		Tips Exam.	Live Larvae	Dead Larvae	Missing Larvae	Tips Exam.	Live Larvae	Dead Larvae	Missing Larvae	
Check	—	25	25	0	1	50	38	0	12	None
						50	36	0	14	
Parathion, 15%	1	25	25	1	0	50	42	0	8	None
		25	20	1	7	50	36	1	13	
Parathion, 15%	1.5	25	23	1	1	50	38	1	11	None
		25	18	1	6	50	32	1	17	
Benzene hexachloride, 10% gamma isomer	10 (gamma isomer)	25	19	1	6	50	32	0	19	Sparse
		25	23	0	2	50	28	1	21	
Dichlorodiphenyl dichloroethane 50%	2	25	13	0	12	50	18	2	30	Profuse
		25	14	0	11	50	10	6	34	
DDT, 50%	2	25	14	1	11	50	6	4	40	Profuse
		25	8	0	17	50	10	5	35	

[1] Materials applied April 12 and 13, 1949.

Table 1.—Mortality of adult males of *Periplaneta americana* L. exposed to dusts of a synthetic pyrethroid and of pyrethrins. Average of 4 runs.

Material	Dosage	Mortality in 4 Days
	Mg.	*Per Cent*
Synthetic pyrethroid 0.6%	25	16
	12.5	8
	6.2	7
Pyrethrins 0.6%	25	65
	12.5	13
	6.2	17

Table 2.—Mortality of adult males of *Periplaneta americana* L. exposed to dusts containing 0.6 per cent of a synthetic pyrethroid, alone and with 3 per cent of various synergists. Sixty roaches, 15 roaches per test exposed to 25 mg. of dust, average of 4 tests.

Synergist	Knock-down in 6 Hours	Mortality in 4 Days
	Per Cent	*Per Cent*
None	1	35
Piperonyl butoxide	6	80
N-propyl isome	7	87
Sesame oil	1	22
Piperonyl cyclonene	7	75
Pyrethrins (check) 0.6%	11	83

Four commercial products—piperonyl cyclonene, piperonyl butoxide, *n*-propyl isome, and sesame oil containing sesamin—are known to have activating properties when used with the natural pyrethrins. The results of an experiment, conducted in 1949 at the Beltsville laboratories of the United States Bureau of Entomology and Plant Quarantine, dealing with the effect of these materials on the synthetic pyrethroid are reported herein.

Powders containing 0.6-per cent of the synthetic weight by weight, with and without synergist, were used. A 0.6-per cent pyrethrins dust, made from 20-per cent pyrethrum extract, was included for comparison. The required quantities of the active ingredients were dissolved in acetone and impregnated on Attaclay, a form of fuller's earth. The mixtures were evaporated to dryness and passed through a 200-mesh screen. The testing technique has been described by Piquett *et al.* (1947). Adult males of the American cockroach, *Periplaneta americana* L., were used as test insects. Table 1 shows that the new synthetic is less effective against the American cockroach than the natural product. By the addition of synergists at a 5 to 1 ratio, table 2, the effectiveness of the synthetic pyrethroid was increased to where it was as good as the natural product for all combinations tested except with the sesame oil. In preliminary tests it was found that all the synergists, when used alone and at higher dosage than reported here, resulted in little or no mortality. Since petroleum distillate was present in the dust made from 20-per cent pyrethrum extract, and was not in that containing the synthetic, it was thought that the distillate might influence the toxicity of the synthetic. A formulation with the deobase present at the same concentration as in the pyrethrins dust was tested and the results indicated it did not change the toxicity.

The data reported in this paper may indicate synergistic action between the three adjuncts and the synthetic pyrethroid.

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Cattle Grub Distribution in California

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The common cattle grub, *Hypoderma lineatum* (de Vill.), has been recognized in California for many years; however, it was not until 1947 that the northern species, *Hypoderma bovis* (de Geer), was reported from cattle not native to California. At that time, only a few collections of *H. bovis* had been made from the state, and the geographical range and seasonal distribution were unknown.

The data reported here were obtained in cooperation with County Farm Advisors of the Agricultural Extension Service over a two-year period.

Collections were made in 44 counties. The data recorded pertain only to collections from native cattle. Both *Hypoderma bovis* and *H. lineatum* were taken in 34 counties. Only *H. lineatum* was found in 5 counties while only *H. bovis* was collected in the remaining 5 counties.

In California the northern cattle grub was found distributed from Siskiyou County on the Oregon border to and including Imperial County which borders Mexico. To the author's knowledge, this represents the southernmost reported incidence of *Hypoderma bovis* in the United States. It is evident that this species is maintaining itself in its southern distribution because it occurs not only in cattle native to Imperial County but also in the neighboring counties, *i.e.*, San Diego, Riverside, San Bernardino, and Los Angeles.

Studies of seasonal distribution, to be reported in greater detail elsewhere, demonstrate that *Hypoderma lineatum* appears in the backs of cattle earlier than does *H. bovis*, only to be replaced by the latter species later in the season. This probably accounts for the fact that a single species was recorded from some counties where the only collections were made either early or late in the season. The collection of both species was sufficiently general, however, to state that for practical purposes they occur throughout the state.

The relative abundance of the two species is not constant throughout all areas, but in sections where both species are numerous the extended period of emergence on the backs, covering a period of over 6 months, means that at best the previously recom-

mended practice of treating three times at 30-day intervals will not result in adequate control.

Reaction of Certain Fly Strains to DDT and Methoxychlor Deposits[1]

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In 1948, Barber and Schmitt[2] observed that certain fly strains reared at Rutgers University did not react alike to residues of DDT and methoxychlor on plywood panels. In particular, a standard strain of flies developed by the National Association of Insecticide and Disinfectant Manufacturers, (NAIDM) and used by many of its membership, appeared to be resistant to methoxychlor. To develop additional information, flies of the NAIDM strain reared in two different laboratories were compared with a DDT resistant strain (Ellenville flies of eighteenth and nineteenth generations reared in the laboratory) and a laboratory strain (Wilson) believed to be normal in susceptibility to insecticides.

Plywood panels were treated as follows: (1) slurries were sprayed in such manner that 2.76 gm. water was deposited per square foot and deposits of wettable powders were varied by change of dilution. (2) Precise amounts of acetone solutions were brushed on measured areas of plywood. After drying, deposits were exposed to flies in an embroidery hoop cage by setting the cage on the treated surface for exactly 15 minutes. After the exposure, flies were moved to untreated surfaces and fed. Knockdown counts were made at various periods and mortality was determined one day later.

The results of tests of DDT wettable powders show that about 2.5 mg. DDT/sq. ft. was required to kill 100 per cent of Wilson, du Pont NAIDM and Rutgers NAIDM strain flies, but about 15 times more DDT was required to kill 100 per cent of the Ellenville strain (Table 2). This confirms earlier conclusions drawn by Schmitt & Barber, and indicates that the Ellenville strain is about 15 times as resistant to DDT wettable powders as the other strains studied.

Table 2.—Resistance of three fly strains, relative to the Wilson strain, based on minimum deposits of DDT and methoxychlor from wettable powders required to kill 100 per cent of flies.

	Wilson Strain	NAIDM Strain du Pont	NAIDM Strain Rutgers	Ellenville Strain
Deposits of DDT				
mg./sq. ft./100 per cent kill	2.5	2.5	2.5	38
Ratio relative to Wilson[1]	1	1	1	15
Deposits of methoxychlor				
mg./sq. ft./100 per cent kill	4.7	7.2	7.4	6.2
Ratio relative to Wilson[1]	1	1.5	1.6	1.3

[1] Obtained by dividing deposit required to kill 100 per cent of Wilson flies into deposit required to kill 100 per cent of other strain flies.

In the case of methoxychlor wettable powders, the ratio of deposits relative to that of Wilson were 1.5 and 1.6 for NAIDM du Pont and Rutgers respectively, and 1.3 for Ellenville strains (Table 2). At the 50 per cent kill level, the ratios were 1.3, 1.6, and 1.9 in the above order, respectively. In either case, however, the NAIDM strains reared by Rutgers University and by the du Pont Company appear to be equally susceptible within the range of experimental variation. It is probable that the Wilson strain is slightly more susceptible and the Ellenville strain is slightly more resistant to, methoxychlor than the NAIDM strain.

The results of tests of deposits from acetone solutions show that 144 mg. DDT/sq. ft. killed 100 per cent of all flies other than the DDT resistant Ellenville strain (Table 1). On the other hand, 144 mg. methoxychlor/sq. ft. effected higher kill of

[1] Journal Series Paper, New Jersey Agriculture Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.

[2] Barber, G. W. and Schmitt, J. B. 1949. A Line of Houseflies Resistant to Methoxychlor. JOUR. ECON. ENT. 42 (5): 844.

Table 1.—Kill of four strains[1] of houseflies exposed for 15 minutes to deposits of DDT and methoxychlor on plywood.

Deposit Mg./Sq. Ft.	Knockdown/15 Min.				Knockdown/4 Hr.				Per Cent Dead in 1 Day				Total Flies			
	Ru.[1]	Du.	El.	Wl.	Ru.	Du.	El.	Wl.	Ru.	Du.	El.	Wl.	Ru.	Du.	El.	Wl.
Methoxychlor[2]																
2.41 (W)	8	8	5	25	42	61	22	80	39	61	22	80	167	165	133	176
6.14 (W)	29	39	66	83	96	100	100	100	97	99	100	100	158	114	113	164
9.88 (W)	80	33	69	56	100	100	100	100	100	100	100	100	87	61	77	94
144.0 (A)	28	48	28	76	53	68	38	86	53	68	38	86	133	155	118	150
576.0 (A)	15	90	57	12	13	96	38	58	23	95	30	52	47	112	77	86
DDT[2]																
0.51 (W)	0	0		0	2	13		6	20	39		30	106	144		158
1.54 (W)	0	0		0	26	57		58	81	86		78	137	104		166
2.52 (W)	0	0	0	12	75	89	4	99	99	100	7	100	111	152	138	143
6.04 (W)			1				22				19				129	
9.88 (W)			0				70				62				126	
11.2 (W)			3				86				70				59	
28.1 (W)			23				98				98				47	
46.8 (W)			51				99				100				75	
144.0 (A)	16	11	17	19	100	98	26	100	100	100	25	100	102	140	135	172

[1] Ru. and Du.—the current NAIDM fly strain reared by Rutgers University and the du Pont Co., respectively. El. and Wl.—Ellenville, a DDT resistant strain, and Wilson, a laboratory strain, respectively, reared by Rutgers University.

[2] Deposits obtained from commercial water dispersible powders (W) and acetone solutions (A).

Table 1.—Fate of flies of the lines named exposed for the stated time to surfaces bearing the stated deposits.

Insecticide	Residue in Mgm./Sq. in. and Time Exposed	Laboratory		Ellenville[1]		NAIDM[2]	
		Total Flies	Died	Total Flies	Died	Total Flies	Died
		Number	*Per Cent*	*Number*	*Per Cent*	*Number*	*Per Cent*
DDT technical	1						
	15 min.	38	100	46	15	42	100
		60	100	60	38	43	100
	2						
	15 min.	42	100	61	10	64	100
		70	100	46	17	47	100
DDT pp′ isomer	1						
	15 min.	43	100	53	28	52	100
		78	100	56	36	59	100
	2						
	15 min.	41	100	33	18	54	100
		57	100	66	24	53	100
Methoxychlor (unmodified)	1						
	15 min.	47	75	51	14	62	6
	30 min.	53	100	40	48	50	58
	2						
	15 min.	41	92	39	10	38	24
	30 min.	73	100	60	48	47	75

[1] Eleventh laboratory generation. [2] From puparia received.

Table 2.—Fates of flies of the lines named exposed to surfaces bearing the stated deposits for the times indicated.

Insecticide	Residue in Mgm. per Sq. in.	Time in Minutes	Date Panel Treated	Date Flies Exposed	Laboratory		Ellenville[1]		NAIDM[2]	
					Total Flies	Died	Total Flies	Died	Total Flies	Died
					Number	*Per Cent*	*Number*	*Per Cent*	*Number*	*Per Cent*
DDT technical	2	30	Nov. 11	Nov. 21					237	100
		60	do	do					283	100
		30	do	Nov. 23	106	100	91	19		
		60	do	do	91	100	50	46	107	100
DDT pp′ isomer		30	do	Nov. 21					240	100
		60	do	do					248	100
		30	do	Nov. 23	69	100	90	18		
		60	do	do	123	100	64	42	123	100
Methoxychlor (unmodified)	2	30	do	Nov. 21					246	34
		60	do	do					247	67
		30	do	Nov. 23	102	100	98	29		
		60	do	do	121	100	59	86	73	79
		30	Nov. 22	do	79	100	44	50		
		60	do	do	90	100	74	97	74	55
Methoxychlor (recrystallized 100%)	2	30	do	do	89	100	96	64		
		60	do	do	97	100	79	87	122	73
Gamma isomer Benzene hexachloride	14.4[3]	10	do	do					132	100
Parathion	do	10	do	do					121	100
Chlordan	144[3]	5	do	do					155	100

[1] Twelfth laboratory generation. [2] First laboratory generation at Rutgers. [3] Mgm. per square foot.

Wilson, and lower kill of Ellenville, than NAIDM strain flies. This tends to confirm the wettable powder test results. It is of interest, however, that deposits as high as 576 mg. methoxychlor per sq. ft. failed to kill 100 per cent of any fly strain. It appears, therefore, that methoxychlor in acetone solution is more adversely affected by porous surfaces than is DDT, perhaps because of different absorption or other physical characteristics.

A Line of Houseflies Resistant to Methoxychlor[1]

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In two previous papers[3,4] the resistance of a line of houseflies called the Ellenville line, to DDT residues was described. In the first paper, flies of a

laboratory line, called herein the Wilson line, were used as checks. None of the progenitors of this laboratory line had been exposed to DDT. In the second paper, flies of the current NAIDM line, obtained from Dr. Franklin C. Nelson of Stanco, Incorporated, were used for comparison, in addition to flies of the Wilson line previously used. Tests on residues obtained from acetone solutions of methoxychlor indicated that the NAIDM line possessed some resistance to methoxychlor, but none to DDT. This lack of resistance to DDT in flies showing resistance to methoxychlor seemed to merit further study, since it might well be supposed that a physiological mechanism which provides resistance to methoxychlor would provide resistance to DDT as well, and vice versa.

A series of tests were therefore made in November 1948 to obtain further data on the extent of this apparent resistance in the NAIDM line. The testing method previously described was used in these tests and readings were taken 24 hours after the flies were exposed to the residues. The results are given in tables 1 and 2.

It will be seen that exposures to residues of DDT which killed 100 per cent of the Wilson line also killed all of the NAIDM line flies whereas exposures of flies of the same lines to methoxychlor residues resulted in decidedly less kill to the NAIDM line flies. Ellenville line flies exhibited resistance to residues of both DDT and methoxychlor. No evidence of resistance to the insecticides used, other than methoxychlor, was found in the NAIDM line.

[1] Journal Series Paper, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology.
[2] Deceased December 6, 1948.
[3] Barber, G. W. and J. B. Schmitt. Houseflies Resistant to DDT Residual Sprays. N. J. Agr. Exp. Sta. Bull. 742, 1948.
[4] *Ibid.* Further Studies on Resistance to DDT in the Housefly. JOUR. ECON. ENT. Vol. 42 (2): 287–292.

The Omnivorous Leaf Tier on Field-Grown Cut Flowers in California

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The omnivorous leaf tier, *Cnephasia longana* (Haw.), was first recognized as occurring in California in 1948. At that time it was found to be a serious pest of field-grown cut flowers along the San Francisco peninsula. The damage to these crops appeared to be considerably more severe in the same area in 1949.

IMPORTANCE.—Nearly all of the major field flower crops which are grown near San Francisco are subject to attack by the omnivorous leaf tier. On asters, marguerites, Shasta daisies, bachelor-buttons, strawflowers, chrysanthemums, and other composites, the maturing caterpillars feed largely within the buds of new growth and burrow within the developing flowers. On heather, the caterpillars feed on the tips of new growth or mine the more succulent terminal shoots. The damage to calla lilies, watsonias, gladiolus, daffodils, and iris is largely due to the webbing and feeding of the larvae within the buds or opened flowers. The terminal growth of young acacias is tied and eaten.

Garden plants and nursery stock are also subject to considerable damage. Roses, pansies, violets, poppies, pelargoniums, tulips, carnations, sweet Williams, and many other garden flowers are attacked. The terminal growth of small, woody ornamental plants such as lilacs and magnolias and young fruit trees such as applies and cherries may be tied and eaten. Many common weeds are suitable hosts.

BIOLOGICAL NOTES.—Larval infestations of the omnivorous leaf tier start early in the spring, and the tiny caterpillars first mine within the leaves for several weeks. Near Palo Alto, the first instar larvae were carried by the wind into the fields during the latter part of February, March, and early April of 1949, the peak of initial infestation being late in March.

After leaving the mines, the caterpillars fold leaves or tie them together, and then gradually move to centers of new growth or buds within which to feed. In the Palo Alto area, during 1949, the most severe damage resulted during the latter part of April when most of the caterpillars were reaching maturity. Near Millbrae (only 15 miles north of Palo Alto) there was little evidence of the omnivorous leaf tier during mid-April, but widespread damage occurred during the latter part of May as the caterpillars were maturing in that area.

CONTROL.—Experimental control plots were located in a ten-acre field of asters in Palo Alto. The entire planting as well as many seedlings for an additional ten acres was heavily infested with the omnivorous leaf tier. At the time the plots were sprayed, on April 9, there was an average of 15 per cent of the leaf mines still occupied, mostly by second instar larvae. Many of the larvae were in the third instar, and many were feeding within tied leaves and new growth centers. The asters were approximately 6 inches high.

Each plot contained approximately 50 plants which were segregated in a bed three rows wide. Three plots were left untreated. Two each of 12 randomized plots were treated with different insecticides. A pressure-type hand sprayer was used, the rate of application being such as to insure complete coverage (about 1 gallon per 100 plants).

Parathion 25 per cent wettable powder was used at a concentration of 0.15 pound actual material per 100 gallons of water, DDD 50 per cent wettable powder at a concentration of 1 pound actual material per 100 gallons of water, DDT 50 per cent wettable powder at a concentration of 1 pound actual material per 100 gallons of water, gamma isomer benzene hexachloride 25 per cent wettable powder at a concentration of 0.2 pound actual material per 100 gallons of water, toxaphene 60 per cent emulsion at a concentration of 1.5 pounds actual material per 100 gallons of water, and chlordan 46 per cent emulsion at a concentration of 1 pound actual material per 100 gallons of water.[1]

Control of the caterpillars which had left the leaf mines was evaluated on a basis of field counts of the number of living larvae made on ten plants in each plot. Counts were made both 3 days and 6 days after treatment (Table 1). Considerable mortality was obtained with the parathion, dichlorodiphenyl dichloroethane, and DDT sprays. Negligible kill was observed in the plots treated with toxaphene, gamma isomer benzene hexachloride, and chlordan.

[1] Parathion was furnished by the American Cyanamid Co., DDD by the Rohm & Haas Co., DDT and gamma isomer BHC by the California Spray Chemical Co., and chlordan by the Sherwin-Williams Co.

Table 1.—Average number of live caterpillars (emerged from leaf mines) per aster plant following treatment, based on count of ten plants in each plot.

MATERIAL PER 100 GAL. WATER	3 DAYS AFTER TREATMENT	6 DAYS AFTER TREATMENT
Parathion 25% powder, 0.60 lb.	0.55	0.70
Dichlorodiphenyl dichloroethane 50% powder, 2 lbs.	0.50	0.35
DDT 50% powder, 2 lbs.	0.80	0.50
Toxaphene 60% emulsion, 1 qt.	3.15	3.50
γ Benzene hexachloride 25% powder, 12 oz.	3.80	4.00
Chlordan, 46% emulsion, 1 qt.	4.30	4.25
Check	4.30	4.97

Table 2.—Number of leaf-mining caterpillars living 4 days after treatment, based on counts made in 20 mined leaves from each plot.

MATERIAL PER 100 GAL. OF WATER	TOTAL NO. MINING LARVAE COUNTED	NO. LARVAE ALIVE
Parathion 25% powder, 0.60 lb.	51	0
Dichlorodiphenyl dichloroethane 50% powder, 2 lbs.	42	2
DDT 50% powder, 2 lbs.	21	9
Check	24	17

The entire ten acres of asters, including the experimental plots, were treated by the grower with DDT just one week after the initial spray trials. At this time many of the larvae were in the fourth instar. Subsequent observations over the field indicated that the degree of control obtained by the grower was comparable to that obtained in the original DDT plots.

Because it might be preferable to practice insecticidal control before many caterpillars are protected within the heart of new growth, observations were made on the effect of several materials on the leaf-mining larvae. Counts of mining caterpillars were made in leaves which were selected for infestation 4 days after treatment. The results (Table 2) indicated that parathion killed all caterpillars within leaf mines. Dichlorodiphenyl dichloroethane gave considerable control of the miners and DDT killed some of them.

Plant injury was not observed in connection with any of the materials tested except with parathion. Noticeable spotting of the leaves was evident where the parathion spray was used.

SUMMARY.—The omnivorous leaf tier was first recognized as a serious pest of field-grown cut flowers on the San Francisco peninsula during the spring of 1948. Damage to these crops appeared to be more severe in 1949. Parathion, dichlorodiphenyl dichloroethane, and DDT gave good control of the caterpillars on asters, while γ benzene hexachloride, toxaphene, and chlordan were ineffective at the concentrations used. Some injury to aster plants occurred in the parathion plots.

A Technique for Mounting Aphids and Other Soft Bodied Insects on Slides[1]

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When specimens of insects are sent to specialists for identification, the task can be done much more easily and quickly if the specimens are properly preserved. This is especially true of aphids. The method of mounting described below incorporates features developed by several workers, much of which has been reviewed by Essig (1948), and results in very satisfactory mounts.

The writer has developed this technique for mounting aphids by modifying a process suggested by A. N. Tissot (*in litt.*). This included slitting of the body wall with fine needles, maceration in hot 10 per cent KOH solution until the tissues were dissolved, followed by dissection with the fine needles to remove the embryos and other body contents. This left the specimens perfectly clear after they were neutralized in acid-alcohol and dehydrated through successively stronger alcohol concentrations, then cleared in clove oil before mounting in euparol. A disadvantage of this method is that the specimens must be watched very closely while they are in the hot potassium hydroxide, or they might be overdone, in which case the cuticular pigmentation will fade and the specimens will be too limp. Very limp specimens cannot withstand the change from alcohol to clove oil, which results in the appendages, antennae and hairs becoming shriveled.

With a modification of this technique, the writer has developed the method described below. This technique permits the simultaneous handling of a large number of collections in a short period of time, minimizes distortion of the specimens, better preserves the cuticular pigments, provides for an easy way of transferring specimens from one dish to another, thus avoiding the changing of reagents in a particular dish containing specimens, and produces a more satisfactory mount. The improvements which the writer has made include: (1) Using *cold* 5 per cent KOH for maceration, together with slitting or puncturing of the specimens, which extends the maceration time so that it is easier to control the degree of solution of the tissues without constant attention being necessary (a solution of 5 per cent sodium hydroxide seems to be more desirable since it bleaches the skin pigments less). If the body wall is not opened, the body contents will usually swell and force the material into the wings. "Ballooning" of the wings is to be avoided. The maceration time will be prolonged (up to one week or more) in unpunctured specimens, while otherwise an overnight soaking will ordinari y suffice. (2) The use of a special instrument to transfer specimens from one reagent to another (this instrument is made by soldering four *minuten* insect pins to a needle in such a way that they form a miniature pitchfork, which is set into a wooden handle; the prongs of the "fork" permit draining of excess liquid from the specimen, and they can easily be slipped under the specimen for lifting), (3) A more gradual change from alcohol to clove oil, which lessens the danger of distortion of small parts. The actual technique is as follows:

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1. Fresh specimens are immersed in 70 per cent alcohol in a watchglass. The low surface tension of the alcohol makes it easy to dissect the specimens. (Alcoholic preserved specimens can also be used with this method.)
2. With a fine insect pin set in a wooden holder, large aphids are punctured ventrally near the hind legs, and the point of the pin is protruded out of the specimen near the back end. Then with another similar pin having the point bent into a hook, the skin is rubbed over the first pin until it is slit through. Small aphids are merely punctured with the straight pin in two or three places. These operations permit penetration of the maceration agent, provides an opening for the removal of the body contents, and prevents "ballooning" of the wings by the swelling of the tissues.
3. The specimens are transferred with the "fork" into labelled vials containing a 5 per cent solution of NaOH or KOH, and allowed to stand until examination shows that the thoracic muscles have been dissolved. This may take up to 24 hours, depending on the size of the specimens and room temperature. Usually overnight is sufficient if they are placed in the alkali in the afternoon.
4. The macerated specimens are poured into watchglass and transferred into another glass containing acid-alcohol (10 parts glacial acetic acid. 45 parts 95 per cent alcohol and 45 parts water). With the dissecting needles (one hooked) the embryos are removed from the bodies. Small specimens will usually be clear enough. Five minutes is long enough in the acid-alcohol. Larger specimens might need further maceration. and may be again placed for a while in the alkali. The process may be interrupted here, and the specimens kept in 70 per cent alcohol until they are to be mounted on slides.
5. Dehydration and clearing is done by transferring the specimens successively through the substances listed below. Usually 5 to 10 minutes in each is enough. As each dish is emptied of specimens, a new collection may be started through them behind the first, so that it is possible to have a collection receiving treatment in each dish. The length of time in each dish will then be determined by the time it takes to remove the specimens from the last dish to the slides. As each collection moves along, the labelled vials then follow the respective specimens. The clearing agents are in order as follows:
   a. 70 per cent alcohol
   b. 85 per cent alcohol
   c. 95 per cent alcohol
   d. a mixture of 5 parts clove oil and 10 parts alcohol
   e. a half and half mixture of clove oil and alcohol
   f. clove oil.

The specimens are then arranged on a slide in a drop of euparol and a cover glass is applied. The mounting medium on the slides can be hardened by placing the finished slides on a thermostatically controlled hot plate, set at 50° C., for a few days. This method can be used with equal success on other small insects. The writer has taken specimens of dried pinned aphids, *Longistigma caryae* [Harris] from student collections and made remarkably good mounts using this process. The pins were clipped close to the body and the aphids were first wetted with 70 per cent alcohol, then immersed for a while in the alkali solution to loosen the pins. The rest of the treatment was as outlined above.

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County-Wide Control of the Horn Fly with DDT

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During the 1948 horn fly season personnel of the Bureau of Entomology and Plant Quarantine, the Kansas State Extension Service, and the National Live Stock Loss Prevention Board conducted a county-wide horn fly control program in Kiowa County, Kansas. The object of the investigation was to determine the feasibility of eradicating horn flies, *Siphona irritans* (L.), in large areas and to study the influence of community effort in such a program.

The test area covered 720 square miles. An attempt was made to treat all the cattle in the county, approximately 25,000 head, and such farm buildings as seemed necessary to control flies in general. Of approximately 650 farm owners in the county, less than 1 per cent failed to cooperate in the cattle-spraying program. The building-spraying program did not receive such excellent support. It is estimated, however, that 80 to 85 per cent of the buildings in the county were eventually treated. The buildings were treated before the cattle-spraying program was begun, or not until all the cattle had been treated once.

The dates for initial sprays applied to cattle ranged from April 26 to May 25. Pretreatment counts on 77 herds averaged 40.5 flies per animal. This average might be considered too high, since most of the herds checked were south of U. S. Highway No. 54, where conditions were more favorable for horn fly development. The breeds of cattle treated were Shorthorn, Aberdeen Angus, Hereford, Holstein-Friesian, Jersey, and mixtures of these breeds.

The cattle spray was made from 50 per cent wettable powder diluted to contain 0.5 per cent of DDT. The building spray contained 5 per cent of DDT made from 25 per cent emulsion concentrate. Both types of sprays were applied with power sprayers, operated at a pressure of 450 to 500 pounds per square inch on cattle and at 75 to 100 pounds on buildings. During the initial treatment of cattle some herds were more thoroughly treated than others because of lice infestations. Approximately 1 gallon of spray was applied per animal at this time and only slightly less at subsequent treatments.

For convenience the county was divided into three areas. The outer area (0 to 2 miles from the border), the intermediate area (5 to 7 miles from the border), and the central area (10 to 12 miles from the border). Fly counts, especially of herds in the outer area, were made at weekly intervals, usually a quadrant of the county being checked each day. Herds in the central area were checked as time

permitted. When the flies in a herd averaged 25 per animal, or as soon thereafter as possible, the herd was re-treated. Delay in re-treatment was usually due to wheat-harvesting operations or the lack of spraying equipment. Between April 1 and September 3, 1948, approximately 600 herds received a first treatment, 300 a second, 59 a third, and 10 a fourth.

The protection in weeks afforded in the three areas by the first and second spraying were: outer 9.33 and 4.75, intermediate 7.75 and 5.25, central 12 and 9, respectively. In the central area only one complete record was obtained for each spraying, all other herds being sprayed on each occasion before the fly count averaged 25 flies per animal. The protection to herds that were sprayed three and four times is not given because of incomplete records on fly counts or definite spray dates.

The average weekly fly counts per animal from May 31 to September 3 on untreated herds in the county were 55, 38, 35, 58, 152, 232, 249 and 355 for the first 8 weeks, 535 for the tenth week, and 1,044 for the thirteenth week. These counts indicate a slow but gradual build-up of the horn fly throughout the test period. However, the build-up was more rapid from about the seventh week on, and more pronounced in the larger herds south of U. S. Highway No. 54. No doubt the flies on the smaller untreated herds in the northern half of the county were held in check to some extent by adjoining treated herds.

No records were kept on the control of flies in general, but the results of the over-all spraying were excellent. The initial spraying of the cattle did not eradicate horn flies from the county, but it did give much longer protection than had been experienced before. In tests made in Kansas in 1947, the initial treatment protected cattle from horn flies for approximately 4 weeks.

The failure to eradicate the flies with one treatment may be attributable to two factors—(1) lack of adequate biological information on the spring emergence of horn flies in this area, which prevented proper timing of the first application of insecticide, and (2) inadequate spraying equipment for treating such a large area before second-generation eggs were deposited. No doubt the protective period was influenced by the extensive spray program, the movement of some cattle from winter quarters to summer pastures after treatment, the low precipitation and prolonged cool temperatures, and the retention of DDT in the winter coat of hair on the animals.

The second application was less effective than the first, probably because (1) it was applied at higher atmospheric temperatures, (2) the summer coat of hair on the animals did not retain as much DDT, and (3) rainfall and the delay of second treatments when wheat was being harvested resulted in a build-up of flies.

These studies indicate that it is difficult to eradicate the horn fly from large areas, and that in any large-scale control program 100 per cent community effort is essential for its success.

Tetraethyl Pyrophosphate Dusts

KENNETH E. MAXWELL[1] and A. F. SWAIN[2]

The use of tetraethyl pyrophosphate as an insecticide has grown rapidly since its introduction two years ago, and has proven to be a valuable addition to the insecticide field. Its non-stability in water, in which it hydrolyzes rapidly to form relatively non-toxic compounds (Schrader 1947; Martin & Shaw 1947; Hall & Jacobson 1948), has made it particularly valuable where its use is required on edible crops shortly prior to harvest. This non-stability however, has been a serious drawback to its use in a dust carrier. Most common dust diluents either have too high pH or contain sufficient moisture to hydrolyze the tetraethyl pyrophosphate, which makes the mixture insecticidally ineffective shortly after its preparation. Many attempts have been made to produce tetraethyl pyrophosphate dust insecticides, but only one or two such dusts have been prepared commercially that were uniformly effective for more than a few hours after their preparation.

Table 1.—Effect of different carriers containing 0.8 per cent tetraethyl pyrophosphate.

Carrier	Days Exposed	Flies KD_{50}, Min.	Pea Aphids % Kill
Pumicite	0	1	
Kaolin	0	58	
Calcined Gypsum	0	2	
Georgia Clay	0	38	
China Clay	0	55	
Calcined Pumicite	3	4	100
Kaolinite	3	60+	18

In the fall of 1948 the writers inaugurated a research program to determine the effect of different dust diluents, conditioning agents and other additives on the decomposition of dust preparations of tetraethyl pyrophosphate, and to ascertain whether stabilizing agents to suppress hydrolysis could be utilized to prolong the insecticidal effectiveness of the materials in storage. Dusts were prepared by mixing the materials for 30 minutes in a laboratory pebble mill. At first technical tetraethyl pyrophosphate was used at 2 per cent by weight, but later a standard formula containing 50 per cent technical tetraethyl pyrophosphate in solution was used at a rate of 4 per cent by weight to give 0.8 per cent tetraethyl pyrophosphate and 1.2 per cent other ethyl phosphates in the dust mixture. It was found in preliminary tests that such a formula produced a more satisfactory dust than did one prepared from the technical material. In order to obtain accelerated decomposition during storage periods, a 50-gram portion of each batch was placed in an open-top half-pint carton where the dust mixture would remain exposed to the atmosphere. Periodically, after thoroughly mixing the exposed materials, a 50-milligram sample was removed and spread uniformly over 9 cm. filter papers in petri dishes into which 30 to 50 *Drosophila* flies were introduced. The insecticidal effectiveness of the materials was determined by observing the time required for a 50 per cent knockdown (KD_{50}). Supplementary tests were made by dusting uniformly, with a small dust atomizer, individual greenhouse plants well infested with aphids.

A large number of dust carriers were tried, in fact

Pacific Slope Branch Program, 1949.

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[2] Eston Chemicals, Inc., Los Angeles, California.

Table 2.—Effect on conditioners on dusts containing 0.8 per cent tetraethyl pyrophosphate.

CARRIER	CONDITIONER	DAYS EXPOSED	FLIES KD_{50}, MIN.
Calcined Gypsum	None	4	8
Calcined Gypsum	None	6	19
Calcined Gypsum	15% Diatomaceous earth	4	6
Calcined Gypsum	2% Magnesium carbonate	3	— (0% KD @1 hr.)
Calcined Gypsum	2% Tricalcium phosphate	3	24
Calcined Gypsum	1% Silica aerogel	3	3
Calcined Gypsum	1% Silica aerogel	6	21
Pumicite	15% Diatomaceous earth	7	12
Pumicite	15% Calcined perlite	7	47

most of the readily available commercial ones, as well as several others that are not at present commercial. In these tests all of the dust diluents were dried over night in a drying oven at 105° C. to drive off atmospheric moisture, and then sealed in moisture-proof containers until used. Table 1 shows a few typical results. All materials tested, except two, were entirely unsatisfactory. Dusts prepared from pumicite and from calcined gypsum showed relatively high toxicity to flies. By continuing studies of these two carriers it was found that further calcining lengthened the period of effectiveness. to some extent with gypsum and to a considerable extent with pumicite.

The physical condition of dusts prepared from these carriers was such that the addition of a conditioning agent was highly desirable. Tests to determine the effect of conditioners on the toxicity showed that diatomaceous earth and silica aerogel had little or no adverse effect. Table 2 shows the effect of these and a few others, such as magnesium carbonate, tricalcium phosphate and calcined perlite which greatly reduced their effectiveness.

From a search for a stabilizer, non-phytotoxic at dilutions required and preferably soluble in tetraethyl pyrophosphate, there was developed a solution[3] containing 50 per cent technical tetraethyl pyrophosphate as the active ingredient, which materially prolonged the period of effectiveness of the dust mixture (Table 3). Mixtures containing the stabilized solution were more effective with pumicite than with calcined gypsum. After nine days exposure, the pumicite mixture still gave a KD_{50} in 9 minutes and a KD_{100} in 18 minutes.

The relative effects of tetraethyl pyrophosphate and the stabilized tetraethyl pyrophosphate solution with these two carriers show that pumicite was more effective than calcined gypsum and that tetraethyl pyrophosphate solution containing the stabilizer increased the period of effectiveness with both carriers. Such increase was greater with pumicite than with gypsum. Pumicite containing the stabilized solution, when tested after 18 days exposure to the air, still showed high toxicity.

Field tests of commercially prepared dusts with a specially calcined pumicite[3] are being carried on in typical localities throughout the Pacific Coast agricultural areas. To date dusts stored in standard multiwall bags, have shown no loss in toxicity 3 weeks after manufacture. These tests are being continued to determine the maximum period of effectiveness.

SUMMARY.—Accelerated laboratory bioassay tests of tetraethyl pyrophosphate dusts showed that a specially calcined pumicite mixture as the carrier delayed decomposition of the tetraethyl pyrophosphate for a longer period of time than any other carrier. These tests also showed that the addition of a stabilizer to a tetraethyl pyrophosphate solution[4] further prolonged the period of insecticidal effectiveness markedly as compared with that shown by tetraethyl pyrophosphate alone. Field tests in several different localities verified the laboratory findings.

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[3] *Tetron-DX.*
[4] *FRIANITE-HP* (California Industrial Minerals Company).

Thrips on Asparagus

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In past years, and on rare occasions, thrips have been troublesome on green asparagus intended for processing. No direct damage has been observed and the problem has been limited to thrips contamina-

Table 3.—Effect of dusts containing 0.8 per cent tetraethyl pyrophosphate plus stabilizer.

CARRIER	ADDITIVE	DAYS EXPOSED	*Drosophila* FLIES KD_{50}, Min.	*Drosophila* FLIES KD_{100}, Min.
Calcined Gypsum	Tetraethyl pyrophosphate	9	(0% KD@1 hr.)	
Calcined Gypsum	Tetraethyl pyrophosphate[1]	4	3	7
Calcined Gypsum	Tetraethyl pyrophosphate	6	7	25
Calcined Gypsum	Tetraethyl pyrophosphate	8	23	—
Calcined Gypsum	Tetraethyl pyrophosphate	9	56	—
Pumicite	Tetraethyl pyrophosphate	4	3	7
Pumicite	Tetraethyl pyrophosphate	6	5	9
Pumicite	Tetraethyl pyrophosphate	8	6	11
Pumicite	Tetraethyl pyrophosphate	9	9	18

[1] Tetron DX solution containing 50% technical tetraethyl pyrophosphate plus stabilizer.

tion of the canned or frozen food products. During the past season conditions have apparently been ideal for the development of large thrips populations on some crops and weeds. The presence of thrips in more than normal abundance resulted in numerous complaints of thrips infesting asparagus.

The problem became so acute that it was deemed desirable to investigate it and to determine under what conditions asparagus was subject to serious attack. It was found that there were a number of contributing causes. The thrips appeared to be from the following sources: (1) drying weeds in areas surrounding asparagus fields, (2) maturing crops adjacent to asparagus, (3) alfalfa or other hay crops being cut, and (4) weeds within asparagus fields. While all the above sources of thrips appeared to have a bearing on the problem, serious infestation in asparagus was mostly associated with fields that were weedy.

The species of thrips involved belonged mostly to the flower thrips group or *Frankliniella* complex. There was little or no evidence that the thrips were breeding on the asparagus. In fact, there was little opportunity for this because the asparagus spears are cut within a few days after they appear above the ground. Where infestations were encountered it was found that fewer thrips occurred on spears having tight heads than on those where growth had progressed to a point where the heads were loose. Most of the thrips observed were adults.

In order to obtain some measure as to the number of thrips present, spears were collected at random throughout the fields surveyed. The thrips were removed from the spears by holding them over a cardboard box with a suitable background and tapping them a number of times to jar the thrips loose. The dislodged thrips were then counted. In fields that were free of weeds the average infestation per spear was frequently less than 0.1 thrips while in weedy fields it averaged as high as 7 per spear.

The period of time over which the thrips may be troublesome in a given field shows some variation. They are seldom found in destructive numbers for more than a week. Once the spears on which they have congregated are harvested, the remaining crop is relatively free of the pest.

Chemical control of the thrips hardly appears practical. Infestations are usually of short duration and in many cases it is probable that most of the infested asparagus is harvested before it is determined that a serious condition prevails. Further, the thrips may be from a crop on which it would be hazardous to use insecticides or from areas beyond the grower's jurisdiction which, of course, would preclude the use of insecticides. Cultural methods that will discourage weed growth should be practiced and if a serious thrips infestation is suspected, the asparagus spears should be harvested while the heads are tight, because in the presence of migrating thrips the problem becomes much more severe if the heads of the spears are loose.

Table 1.—Comparisons of binders and carriers, State College, 1948.

Bait Material	Moths Captured	Per Cent of Series	Per Cent Ratio to Control
	Period of Test April 9 to April 27		
Dibutyl sulfide 15 cc. Apple pomace 75 g. Curbay binder 100 cc.	59	12.19	50.43
Safrol 15 cc. Apple pomace 75 g. Phenylacetic acid 10 g. Curbay binder 100 cc.	65	13.43	55.56
Safrol 15 cc. Sassafras bark 50 g. Curbay binder 75 cc.	62	12.81	52.99
Sassafras bark 50 g. Yeast 10 g. Gum arabic glue 50 cc.	44	9.09	37.61
Chopped garlic 25 g. $KMNO_4$ & $K_2Cr_2O_7$ 2 g. each Sawdust 75 g. Gum arabic glue 50 cc.	42	8.68	35.80
Casein 10 g. Yeast 10 g. Sawdust 60 g. Gum arabic glue 50 cc.	42	8.68	35.90
Amygdalic acid 15 g. Yeast 10 g. Sawdust 75 g. Gum arabic glue 50 cc.	53	10.95	45.30
Control: Cane Syrup, 10% in water	117	24.17	100.00
	Period of Test June 6 to July 27		
Dibutyl sulfide 15 cc. Sawdust 75 g. Pine tar shorts 100 cc.	3	1.03	4.55
Safrol 15 cc. Sawdust 75 g. Pine tar shorts 100 cc.	51	17.53	77.27
Dibutyl sulfide 15 cc. Apple pomace 75 cc. *Thiokol WD-2* 50 cc.	6	2.06	9.09
Safrol 15 cc. Apple pomace 75 cc. *Thiokol WD-2* 50 cc.	87	29.90	131.82
Chopped garlic 25 g. Dry lime sulfur 25 g. Sawdust 20 g. Plaster of Paris & water 50 cc.	36	12.37	45.45
a-amino acetic acid 10 g. Sawdust 75 g. Curbay binder 100 cc.	15	5.15	22.73
Naphthalene acetic acid 10 g. Sawdust 75 g. Curbay binder 100 cc.	27	9.28	40.90
Control: Cane Syrup, 10% in water	66	22.68	100.00

Processing of Aromatic Chemicals as Solid Baits for Codling Moth

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The successful development of solid baits for the trapping of the codling moth has been previously described (Eyer 1945). Since then further improvements have been effected by employing more attractive constituents and their use has been extended to the trapping of other species.

These solid baits consist of three phases: 1) the attractant which is an aromatic compound, 2) the carrier which is a porous material capable of absorbing large quantities of the attractant and, 3) a binder which is a plastic material which preferably binds

Pacific Slope Branch Program, 1949.

Table 2.—Comparison of attractants for Mexican bean beetles, State College, 1947.

Bait Material	Generation and Period of Test											
	Second 7/6–8/4			Third (I) 8/12–9/8			Third (II) 8/27–9/26			Fourth 10/18–11/8		
	Av. No. per Trap	Per Cent of Total Catch	Percentage Ratio to Water Check	Av. No. per Trap	Per Cent of Total Catch	Percentage Ratio to Water Check	Av. No. per Trap	Per Cent of Total Catch	Percentage Ratio to Water Check	Av. No. per Trap	Per Cent of Total Catch	Percentage Ratio to Water Check
dl-B-phenyl alanine— 25 g. Sawdust — 100 g. Gum arabic — 350 g. Water —1000 cc.	3.5	42.42	466.67	4.75	43.18	475	2.75	31.43	91.67	3.25	30.23	185.75
Pine extract (Palustrex) 50 cc. other ingredients as above	2.0	24.24	266.67	2.0	18.18	200	1.00	11.43	33.33	2.25	20.93	128.57
Powdered vetch leaves 50 gm. other ingredients as above	2.0	24.24	266.67	3.25	29.54	325	2.00	22.85	66.67	3.50	32.56	200
Water check	0.75	9.09	100.00	1.0	9.09	100	3.00	34.29	100	1.75	16.28	100

the carrier and attractant into a water resistant solid and yet allows a free emanation of the attractive principle. Safrol has given more consistent catches of the codling moth than any other attractant tested and it has the advantage of butyl sulfide in that it is not toxic to the moths which can be removed daily and used for securing oviposition and hatching data, thus adding accuracy to the records when used for timing cover sprays. Sawdust, which was first used as a carrier, was later replaced by apple pomace or sassafras bark, either of which was found to slightly increase the efficiency of the bait because of their intrinsic attractiveness (Table 1). Of the plastics tested as binders[1] a yeast-free carbohydrate manufactured from sugar cane refuse by the U. S. Industrial Chemicals Company and used commercially in the smelting industry for making cores and briquets, has proved highly satisfactory. When once thoroughly hardened into a bait, this binder is moderately weather resistant. Two other binders which are highly weather resistant are allyl sucrose, a furniture lacquer, developed by the Bureau of Industrial and Agricultural Chemistry and a polysulfide "latex" preparation.[2] The latter is related to rubber and manufactured commercially as a spreader and sticker for insecticides and fungicidal sprays.

Although none of the solid bait formulations have given as high catches of codling moths as fermenting baits, their performance has paralleled them and even excelled them during the moth flights of summer generations when temperatures were excessively high (Fig. 1). Moreover, they possess the advantage of being highly selective, and have been successfully used by orchardists in a number of different fruit growing localities in New Mexico and also in Wisconsin, where our Extension Entomologist was located in 1946 and 1947.

Another insect for which solid baits have been found useful is the Mexican bean beetle, *Epilachna varivestis* Muls. In the southern part of the state, the bean beetle overwinters in the bean fields or adjoining ditch banks and hedge rows but in the central and northern portions, as shown by Douglass (1933), it is frequently carried long distances by air currents and hibernates in forests of ponderosa pine and Gambel oak considerable distances from the fields in which they developed. In order to trace the spring and fall movements of this insect migration, traps of various designs including tanglefoot screens and weather vane types were tested in the fall of 1946 and the spring of 1947 (1947). Little success was obtained with these and consequently Japanese beetle traps were substituted. These were found to capture small numbers of beetles in or near bean fields, when the Mason jar receptacle was filled with water. A series of amino acids known to be present in leguminous plants were processed as solid baits with sawdust as the carrier and gum arabic as a binder. The Amino acid, dl-*x*-phenylalanine, and powdered vetch were both demonstrated to increase the numbers of beetles caught in the traps (Table 2). These preliminary findings suggest that a more attractive bait can be developed through further tests of attractants, carriers, and binders and the problem is still under investigation. It was also observed that several species of cutworm moths, particularly *Cirphis unipuncta* (Haw.) and *Agrotis orthogonia* Morr., may be captured with solid type baits with

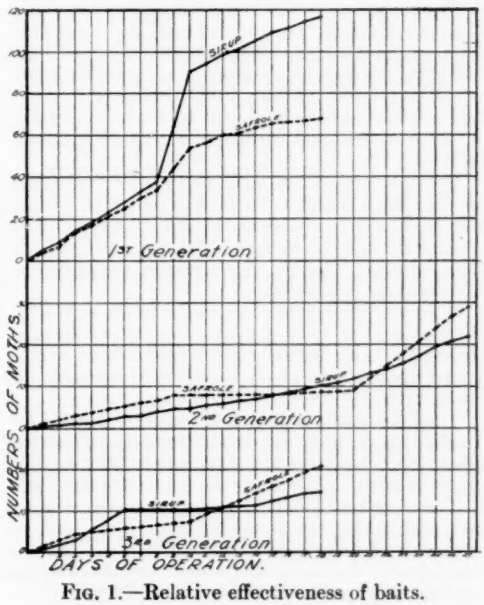

FIG. 1.—Relative effectiveness of baits.

[1] *Liquid Curbau.*
[2] *Thiokol WD-2.*

ethyl acetate, iso butyl phenyl acetate, and related esters used as attractants. The greater degree of selectivity exhibited by solid baits when provided with the proper attractant is important from an experimental standpoint, since it makes possible the comparing of closely related aromatic chemicals by a procedure which eliminates the many undesirable compounds necessarily found through interaction in fermenting baits.

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Field Tests to Control the Mite *Penthaleus major*

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The mite, *Penthaleus major* (Dugès) has long been known as an agricultural pest of sporadic importance. The use of new materials for its control is here reported for the first time.

Penthaleus major was first reported from western North America[1] by Banks (1917) on the basis of specimens which were collected from wheat in Arizona and Oklahoma. Essig (1939) reported the mite as being injurious to peas in northern California. Campbell (1941) reported similar injury to peas and other plants which he had observed in northern California as early as 1914–15.

Penthaleus major has been recognized for many years in southern Australia, Tasmania, New Zealand, and South Africa where it is known as the "blue oat mite" because of its damage to oats and other cereal crops or as the "pea mite" because of its damage to peas, lucerne, or clover. In France and Italy it has been reported mainly as a pest of peas and lettuce.

Injury occurs during cool, wet, winter and spring months when the mites are feeding on young, tender plants. The leaves become bleached and distorted and, in the case of severe infestations, young plants may be killed. The hot, dry summers are passed as the egg stage in the soil.

A severe infestation of *P. major* in an eight-acre field of peas in Contra Costa County, California, during the early spring of 1949, provided an opportunity to test several of the newer insecticides for its control.

The experiment consisted of four checks and four treatments, each replicated four times in randomized plots. Each replicate was 0.05 acre in size. At this date the pea plants were about 1.5 to 2 inches high.

Three per cent DDT,[2] 1 per cent parathion and 1 per cent tetraethyl pyrophosphate were used as dusts, the applications being made with a rotary hand duster. Parathion 25 per cent wettable powder was also used at a concentration of 1.2 pound per acre, the spray being applied with a 3-gallon knapsack sprayer.

Table 1.—Rate of application and effect of various materials on *Penthaleus major*.

TREATMENT	POUNDS ACTUAL MATERIAL PER ACRE	NUMBER OF MITES ON 80 PLANTS		
		Pretreatment	Post-treatment	
			3 days	10 days
Check	—	443	179	116
DDT, 3% dust	0.6	465	2	1
Parathion, 25% wettable	1.2	454	8	4
Parathion, 1% dust	0.23	374	1	0
Tetraethyl pyrophosphate, 1% dust	0.21	436	19	12

A measure of the degree of infestation and control was obtained by field counts of mites on the plants and on the soil at the base of the plants. The mites associated with twenty plants in each replicate were counted, 80 plants being examined for each treatment.

On March 4, one day preceding treatment, there was an average of 5.4 mites on each of the 400 plants examined. Three days following treatment the mites were practically eliminated on each of the acaricidal plots, and they were further reduced in numbers at the end of 10 days (Table 1).

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[1] As *Notophallus viridis* Banks. Other references in the literature include the names *Penthaleus haematopus* Koch, *P. erythropus* Koch, *P. insulans* Thorell, *P. longipilus* Canestrini, *Notophallus bicolor* Froggatt and *N. dorsalis* Banks.

[2] Dusts were supplied by the California Spray-Chemical Corporation. Parathion wettable powder was furnished by the American Cyanamid Company.

Dusting for Sheep Tick Control

D. G. DENNING

During the spring of 1948 and 1949 experiments were conducted in Wyoming to determine the efficacy and practicability of controlling the sheep tick, *Melophagus ovinus* L., on large bands of sheep under Wyoming range conditions. It was felt that the most economical and simplest method of control would be immediately after shearing and before lambing. At this period in Wyoming, late April, May, and early June, the control method may be employed at a time when all the sheep are at hand.

To overcome an objection of the sheepmen to wetting the sheep at a time when a possible change to cold weather may cause heavy loss and when water is frequently unavailable to carry on a spray program it was decided to carry on the initial experiments with a dust. The dust originally used was similar to that reported by Matthysee:[1] 1 part of

Pacific Slope Branch Program.

5 per cent rotenone, in a carrier to which was added 2 per cent of #10 motor oil. Other dusts have subsequently been experimented with such as a cyclonenepyrethrin dust,[2] and a 0.5 per cent rotenone dust to which was added 1 per cent of 6 per cent gamma benzene hexachloride.

A crop row duster with a 16 hose outlet was used with the nozzles inserted in a frame of 2 by 6 lumber. This frame is adjustable for width and height and was placed at the end of the dusting chute. The nozzle arrangement is as follows: 2 at the top, 4 on the bottom, each 2 placed from 1–2 feet apart, and 5 on each side. The duster was operated by a 6-horse power engine which developed approximately 2500 R.P.M. The output was adjusted so that the amount was a trifle over 2 pounds per minute.

The dusting procedure is as follows: as soon as the sheep have been sheared they are forced into a squeeze pen which leads to the dusting chute. The dusting chute should be a minimum of 20 feet in length and narrow enough to prevent the animals from turning around. It is necessary that one man be stationed at the junction of the squeeze pen and dusting chute, and one near the duster so that a rapid movement of the animals through the dust may be maintained. An electric stock prod was found to be an important adjunct to the man stationed near the duster. Thus handled approximately 2000 sheep per hour may be dusted, at a cost of approximately one cent per head. Actual control of the sheep tick with this sort of arrangement using 0.5 per cent rotenone dust varied from about 90 to 100 per cent.

Sheep tick counts on untreated ewes selected at random were as follows:

	Live Ticks		*Live Ticks*
Ewe 1	38	Ewe 11	203
" 2	19	" 12	63
" 3	53	" 13	272
" 4	35	" 14	39
" 5	15	" 15	47
" 6	80	" 16	178
" 7	208	" 17	28
" 8	143	" 18	45
" 9	17	" 19	311
" 10	9	" 20	27

Sheep tick counts on ewes dusted with a 0.5 per cent rotenone dust selected at random 7 days after treatment were as follows:

Ewe 1	0
" 2	2
" 3	0
" 4	0
" 5	3
" 6	1
" 7	0

Sheep tick counts on ewes dusted with a 0.5 per cent rotenone dust selected at random 12 to 14 days after treatment were as follows:

Ewe 1	12	Ewe 7	6
" 2	0	" 8	0
" 3	1	" 9	1
" 4	0	" 10	0
" 5	1	" 11	0
" 6	0		

CONCLUSIONS.—Preliminary experiments to control the sheep tick by dusting with 0.5 per cent rotenone dust is presented. Initial results indicate that early spring dusting, after shearing and before lambing, may prove practical under range conditions. With proper handling of the sheep and employing the suggested chute and nozzle arrangement approximately 2000 animals may be treated per hour at a cost of about one cent per head. No deleterious effects to the sheep have been observed.

[1] JOUR. ECON. ENT. 33 (3): 285–290. 1945.
[2] Kindly furnished to the Wyoming Experiment Station by the U. S. Industrial Chemicals Corporation.

Two Generations of European Fruit Lecanium in Southern Pennsylvania[1]

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On peach trees in southern Pennsylvania orchards, the European fruit lecanium, *Lecanium corni Bouché*, overwinters as a nearly full grown nymph in protected spots on the bark. In appearance it is a small, brown, flat insect covered with a thin coat of wax. Occasionally during warm periods in the winter of 1948–49, nymphs were observed moving about on the trees.

About the time buds of peach reach the pink stage of development, the nymphs go through a final molt. With this molt, the scales change markedly in appearance. McDaniel (1930) describes the adult males as flat and elongated with conspicuous ridges, and the adult females as smooth, broadly oval, and convex.

Adult females lay eggs during May and early June. Eggs of this brood hatch in late June, and the nymphs move to the undersides of the leaves where they remain until mid-July.

After the nymphs move back to the wood, they molt. Adult females mature rapidly and begin laying eggs about August 1. During late July and early August, adult first brood females secrete honeydew copiously. Control measures are frequently needed at this time to prevent damage to the crop, Asquith (1949).

Eggs of the second brood hatch from mid-August to mid-September. The nymphs of this generation also move to the leaves. At the time of the first heavy frost in the fall, they start moving back to the wood. Overwintering nymphs settle down under buds and in crevices on the bark where they stay all winter unless stimulated by unseasonably warm temperatures.

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[1] Authorized for publication on July 22, 1949 as paper No. 1530 in the Journal Series of the Pennsylvania Agricultural Experiment Station.
[2] Acknowledgment is made of the valued assistance of Nelson F. Kane, Edgar M. Raffensperger and Guy A. Herring.

Field Experiments for Control of Shot-Hole Borer[1]

EDWARD W. ANTNON[2]

During the past two years in North Central Washington, there has been an extremely heavy infestation of the shot-hole borer, *Scolytus rugulosus* (Ratz.), on cherries, peaches and apricots in spite of the abundance of the parasite, *Cheiropachus zolon* (L.).

adults enter the cambium in the fall may insure some degree of control, further studies were initiated to determine the degree of control obtained from these insecticides in both spring and fall applications.

Fearful that DDT alone would lead to a build-up of mites, combinations of DDT and parathion were employed. DDT was also used alone for comparison. All applications were made with a power sprayer at 500 lbs. pressure. The results are summarized in table 2.

The mortality was evaluated by counting all dead

Table 1.—The effect of sprays on *Scolytus rugulosus* for 1947 on cherries.

DATE	TREES	TREATMENT (PER 100 GALS.)	FRESH ENTRIES	DEAD ADULTS	LIVE ADULTS	LIVE LARVAE[1]
9–18	3	1 lb. 25% wettable parathion	409	149	3	53
	5	2 lb. 50% wettable DDT	199	9	1	—
9–22	8	1 lb. 25% wettable parathion	204	10	2	—
	8	2 lb. 50% wettable DDT	302	17	0	1
Total	24		1114	185	6	54

[1] No dead larvae observed.

Table 2.—The effect of sprays on *Scolytus rugulosus* for 1948 on apricots.

TREES	TREATMENT (PER 100 GALS)	DATE	DATE CHECKED	DEAD ADULTS	LIVE ADULTS
7	2 lbs. 50% wettable DDT	6–1	6–4	101	10
			6–5	87	6
			6–7	67	2
			6–8	33	0
7	1 lb. 50% wettable DDT plus 1 lb. 25% wettable parathion	6–1	6–4	103	8
			6–5	92	5
			6–7	79	2
			6–8	67	3
6	Control, no treatment		6–4	1	82
			6–5	3	50
			6–7	0	18
			6–8	0	20
4	1 lb. 50% wettable DDT plus 1 lb. 25% wettable parathion	9–13	9–14	1840	1
			9–16	856	0
			9–17	31	0
4	Control, no treatment		9–14	2	230
			9–16	3	152
			9–17	0	188

1947 EXPERIMENTS.—Parathion[3] and DDT sprays were applied to 24 infested cherry trees in the Wenatchee Heights area in September with a *Hardie* sprayer at 300 lbs. pressure. The degree of control was ascertained by dissecting branches and twigs for larvae and adults 2, 5, 7, 10 and 30 days after treatment. The data are embodied in table 1.

Only a few adults were killed in their burrows and no dead larvae were found following application. Two days after spraying all adult activity ceased, but upon examining untreated trees nearby, adult beetles were found to be active at 2 days and 1 month after the principal trees were treated. The latter showed 85 to 100 per cent successful entries by adults in 405 fresh openings examined on 12 trees.

1948 EXPERIMENTS.—Since the 1947 results indicated that DDT or parathion applied when the borers collected on a canvas placed under the sprayed trees. Several days following treatment, numerous sparrows, pheasants and other wild birds collected on the canvas to devour the dead beetles, consequently the counts recorded in Table 2 are undoubtedly low.

SUMMARY.—DDT, parathion, or a combination of the two may be used for the control of the shot-hole borer on stone fruits if applied at the peak of adult activity. These sprays, however, are not apparently effective against adults or larvae within the cambium.

[1] Published as Scientific Paper No. 835, Washington Agricultural Experiment Stations, Institute of Agricultural Sciences, State College of Washington.

[2] Assistant Entomologist, Tree Fruit Experiment Station, Wenatchee, Washington.

[3] *Thiophos* furnished by the American Cyanamid Co.

The Effects of DDT, Benzene Hexachloride and Parathion on the Honeybee

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With the development of many new insecticides, it is desirable that their effects on beneficial insects be determined in order that such materials can be avoided or at least used with caution if they are found to be highly toxic to the honeybee. Butler & Shaw 1948, and Butler 1948[1] made a study of the comparative toxicities of various insecticides to the honeybee under laboratory conditions. Later some field tests were conducted to try to determine the relative toxicity of DDT, benzene hexachloride and parathion. The present paper will present the comparison of data from the laboratory and field and in addition some data obtained by exposing bees to possible residual action of the three materials.

SPRAYS.—The laboratory spraying tests were conducted by spraying a group of 100 to 200 bees with a hand sprayer. Care was taken to use the same number of strokes. Following treatment, the bees were placed in wooden cages with screen wire tops. They were fed a 1-to-1 sugar syrup and observed. In the field, from 50 to 100 bees were confined in 3-inch square cages made of 8-mesh hardware cloth. These cages of bees were hung in cherry and apple trees in bloom and received applications of the insecticides as the trees would if treated normally. Following the treatment, the bees were shaken into clean cages, fed a 1-to-1 sugar syrup and observed.

DUSTS.—In the laboratory, 100 to 200 bees were treated with a dust applied by means of a hand duster. Then they were placed in wooden cages with wire screen tops, fed a 1-to 1 sugar syrup and observed.

In the field, bees were confined in the wire screen cages. These were hung in trees and the caged bees received the insecticides as applied to the tree with a rotary hand duster. Following this treatment, the bees were transferred to clean cages and were fed sugar syrup.

MIST APPLICATION.—As a part of the field tests, bees in screened wire cages were exposed to the application of insecticides applied by a turbine mist blower. Following the application of the insecticide, the bees were handled as outlined in previous experiments.

DISCUSSION OF RESULTS.—*Benzene hexachloride.* As a dust, this material produced 100 per cent mortality within 2.5 hours under laboratory conditions. Under field conditions a mortality of 94 per cent resulted within 24 hours.

As a spray, benzene hexachloride produced mortalities of 90 and 100 per cent under laboratory and field conditions respectively within a period of 6 hours.

Mist applications of benzene hexachloride produced 100 per cent mortality within 2.5 hours.

DDT.—As a dust under laboratory conditions DDT produced 100 per cent mortality in 12 hours. This was significantly longer than the period necessary for the same mortality with other dusts used in the experiments. Under field conditions, DDT was the least toxic of the three materials compared in this article.

As a spray, under laboratory conditions, DDT did not appear highly toxic; in fact it seemed to be relatively non-toxic. Under field conditions, DDT produced a mortality of 97 per cent within 24 hours.

A mist application of DDT, applied by means of a turbine blower produced a mortality of 61 per cent within 24 hours.

Parathion.—As a dust this material under laboratory conditions produced 100 per cent mortality within 24 hours. Under field conditions the same mortality was produced in the same time.

As a spray, parathion produced 100 per cent mortality within 2.5 and 4 hours respectively under laboratory and field conditions.

TOXICITY OF TREATED FOLIAGE TO BEES.—In order to determine the possible danger resulting from the visits of bees to treated foliage, the following experiments were conducted. Sleeve cages of 8-mesh hardware cloth were made. In these, 50 to 100 bees were placed. The cages were placed over treated blooms immediately following the application of insecticides and left for 30 minutes. Following this, the cages were removed to the laboratory and the bees supplied with a 1-to-1 sugar syrup. Observations were made of the actions and rate of mortality of the bees.

RESULTS.—At temperatures of 40 to 50° F. there was no significant difference in the results of DDT, benzene hexachloride and parathion dusts. At temperatures of 60 to 65° F. both parathion and benzene hexachloride as sprays produced 100 per cent mortality within 24 hours. Parathion dusts and DDT spray were quite toxic also. Both benzene hexachloride and DDT as dusts appeared to be only slightly toxic under the conditions of this experiment.

Some data were taken of the residual action of the insecticides tested in these experiments by catching bees visiting treated blooms, confining them in wire cages and feeding them while insufficient data were obtained to permit any specific conclusions the rapid mortality of many of the bees on treated bloom indicates that even after 24 hours some of the materials were still toxic to bees.

EFFECTS OF INSECTICIDES ON NUCLEUS HIVES.—Three 4-frame nucleus hives were in the orchard at the time of application of the insecticides. Since these were under specific trees, each received an exposure to a different insecticide, and as it happened, a different type of application.

The results obtained are reproduced in order that other workers engaged in the problem of obtaining toxicity of insecticides to bees may have access to the data. One of the hives received benzene hexachloride as a spray; no visible injury resulted. A second hive received DDT as a mist application; again no serious results developed. A few paralyzed bees were observed in the bottom of the hive. The third hive received parathion as a dust; this treatment reduced the population by 33 per cent. In addition, several dead pupae were found in front of this hive for 2 days following the application. In no case was the queen killed.

CONCLUSIONS.—Benzene hexachloride in all laboratory and field tests was very toxic to bees. DDT was very toxic in laboratory dusting experiments. It was quite toxic in spray and mist applications under field conditions. DDT in the laboratory spraying and also in field dusting was comparatively non-toxic. The reasons for these reversals under field and laboratory conditions are not known. Parathion was highly toxic under both laboratory and

[1] Unpublished thesis, University of Massachusetts.

field conditions when applied either as a spray or as a dust.

Considerable danger to bees exists for at least 24 hours following an application of either benzene hexachloride or parathion to bloom visited by bees.

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Control of the Cowpea Curculio

GEORGE P. WENE, *Texas Agricultural Experiment Station, Substation No. 15, Weslaco*

The injury done by the cowpea curculio, *Chalcodermus aeneus* Boheman, is a limiting factor in the production of Black Eye peas throughout the Rio Grand Valley of Texas. Arant (1938) recommends dusting with sodium fluosilicate for the control of this insect. Since this material is unavailable locally, preliminary experiments were conducted in order to test the efficiency of the newer insecticides as controls for the cowpea curculio, in comparison with cryolite, which is now being usd.

METHODS AND MATERIALS.—The first experiment was conducted on Black Eye peas. The plots were 50 feet long and 12 feet in width. The treatments applied are shown in table 1. Each treatment was replicated three times. The dusts were applied with rotary hand dusters at approximately 25 to 30 pounds per acre. The first application was delayed until some cowpea curculio injury was noticed. Three treatments were applied at 5, 6 and 10 day intervals. Control was determined by examining 100 bean pods in the middle two rows 6 days after the second and third applications.

Table 1.—The effectiveness of various insecticides in reducing cowpea curculio infestations on Black Eye peas.

TREATMENTS	PER CENT PODS INFESTED AFTER	
	2 Applications	3 Applications
DDT 5.0%	3.3	0.7
Cryolite 40.0%	5.3	1.7
Chlordan 5.0%	4.0	2.0
Untreated	15.3	15.6

The second experiment was also conducted on Black Eye peas. The pltos were 50 feet long and 18 feet in width. The treatments applied are shown in table 2. Each treatment was replicated three times. As in the first experiment, the dust applications were delayed until an infestation became apparent. Two applications of dust were applied at 6 day intervals. Data were taken in the same manner as in experiment 1, five days after the final application.

The third experiment was conducted in a field of Purple Hull peas. The plots were same in size as those of experiment 1. The treatments are shown in table 3. Each treatment was replicated three times,

Table 2.—The effectiveness of various insecticides in reducing cowpea curculio infestations on Black Eye peas.

TREATMENTS	PER CENT PODS INFESTED
Cryolite 40.0%	2.7
Ryanex 50.0%	14.7
Parathion 1.0%	3.3
Benzene hexachloride (gamma content) 1.0%	10.0
Dichloro-diphenyl-dichloroethane 5.0%	5.7
Untreated	17.6

and applied in the same manner. As in the case of the other experiments, treatment applications were delayed until the infestation was noticed on the beans. A heavy rain fell within a few hours after the first application, so the field was re-dusted two days later. A third application was applied six days after the second application of dust. Data were taken in the same manner as in the other two experiments, 6 days after the final dust applications.

DISCUSSION.—As mentioned before, the plots in the first experiment received three dust applications. The data in table 1 indicate that cryolite, DDT and Chlordane will control the cowpea curculio. Arant (1938) was not able to obtain commercial control of this insect when cryolite was used at the rate of eight pounds per acre. This difference in degree of control obtained may be partially explained by the fact that approximately three times as much cryolite dust was used in this experiment. The data also show that a 5.0 per cent DDT dust is slightly superior to the 40.0 per cent cryolite dust. A 5.0 per cent chlordan dust proved to be as effective as the cryolite dust, and like DDT should be investigated further.

The data in table 2 also indicate that cryolite is

Table 3.—The effectiveness of various insecticides on reducing cowpea curculio infestations on Purple Hull peas.

TREATMENTS	PER CENT PODS INFESTED
DDT 5.0%	2.0
Cryolite 40.0%	2.3
Rotenone 1.0%	3.0
Pyrethrins 0.1%+DDT 0.5% (impregnated dust)	3.0
Chlorinated camphene 5.0%	0.0
Untreated	4.0

effective in reducing cowpea curculio infestations. Parathion, used at a 1.0 per cent concentration, also gave good control. The 5.0 per cent concentration of dichloro-diphenyl-dichloroethane reduced the infestation greatly but was not as effective as cryolite. Benzene hexachloride and Ryanex were of little value as a control for this pest.

The cowpea curculio infestation, as is shown by the infestation records on the check plots, was too low for a good test in the third experiment. However, trends similar to those in experiment 1, are evident. The data indicate that cryolite dustings did reduce the cowpea curculio infestation. As in the case of experiment 1, DDT proved to be slightly superior to cryolite in controlling this insect. A 5.0 per cent chlorinated camphene gave perfect control of the cowpea curculio, and should be given further trials.

SUMMARY.—The data indicate that applications of 40.0 per cent cryolite, 5.0 per cent DDT, 5.0 per cent chlordan, and 1.0 per cent parathion were effective in controlling the damage caused by the cowpea curculio on Black Eye peas. A 5.0 per cent dichloro-diphenyl-dichloroethane dust was almost as effective as the 40.0 per cent cryolite dust. Chlorinated camphene, used as a 5.0 per cent dust, was very effective, and should be investigated further as the cowpea curculio infestation was low.

Benzene hexachloride, used at a 1.0 per cent gamma concentration, and 50.0 per cent Ryanex dusts are of no value as a control for the cowpea curculio.

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Comparative Effectiveness of Orchard Acaricides

E. J. NEWCOMER and F. P. DEAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Tests of parathion, 1,1-bis(*p*-chlorophenyl) ethanol,[1] toxaphene, bis(*p*-chlorophenoxy)methane,[2] and lorol-2-thiazolinyl sulfide,[3] were made at Yakima, Wash., in 1948 on apple trees infested with both the Pacific mite, *Tetranychus pacificus* Mcg., and the European red mite, *Paratetranychus pilosus* (C. & F.). The relative effectiveness of each material against the two species could therefore be determined as well as the comparative effectiveness of the materials themselves. In all tests DDT was used for controlling the codling moth.

The 4- or 7-tree plots were located at random about the orchard, and 10 representative leaves from each tree were used in making the counts, the mites being removed from the leaves with a brushing machine. Counts of both species of mites on the same leaves were made three times at 10-day intervals late in the summer, beginning 2 weeks after the spray schedule had been completed.

The dates of the spray applications are given below:

Schedule	*June 23*	*July 14*	*August 5*
One spray	—	X	—
Two early sprays	X	X	—
Two late sprays	—	X	X
Three sprays	X	X	X

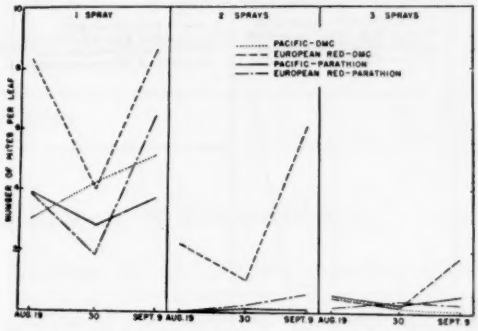

FIG. 1.—Comparative infestations of Pacific mites and European red mites in plots receiving one, two late, and three sprays of 1,1-bis(*p*-chlorophenyl) ethanol and parathion.

Figures 1, 2, and 3 show the infestation in terms of numbers of live mites per leaf. The results from parathion used at 5 ounces[4] of 25 per cent wettable powder are shown in each graph, as it has given better control on the average than other materials, and the other acaricides are compared with it.

A comparison of 25 per cent emulsible 1,1-bis(*p*-chlorophenyl ethanol at 1 pint with parathion in schedules consisting of one, two late, and three sprays is shown in figure 1. A single application of this material did not have quite so long a residual effect as did parathion. Where two late applications were made, the European red mite began building up earlier than the Pacific mite. Even where three sprays were applied, there was evidence that the effect of the material on the European red mite was

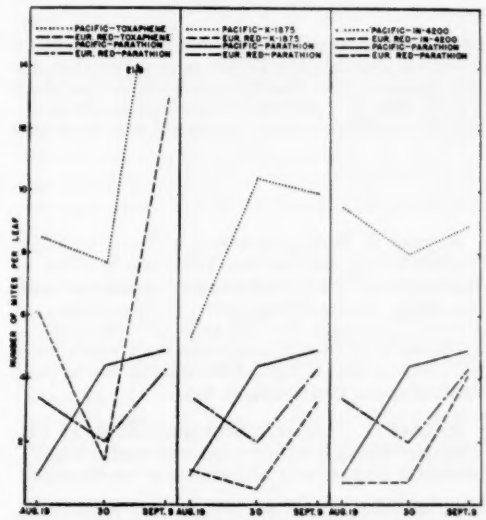

FIG. 2.—Comparative infestations of Pacific mites and European red mites in plots receiving two early sprays. Left: toxaphene and parathion. Center: bis-(*p*-chlorophenoxy) methane and parathion. Right: lorol-2-thiazolinyl sulfide and parathion.

[1] DMC.
[2] *K 1875.*
[3] *IN-4200.*
[4] All quantities used in these tests are for 100 gallons of water.

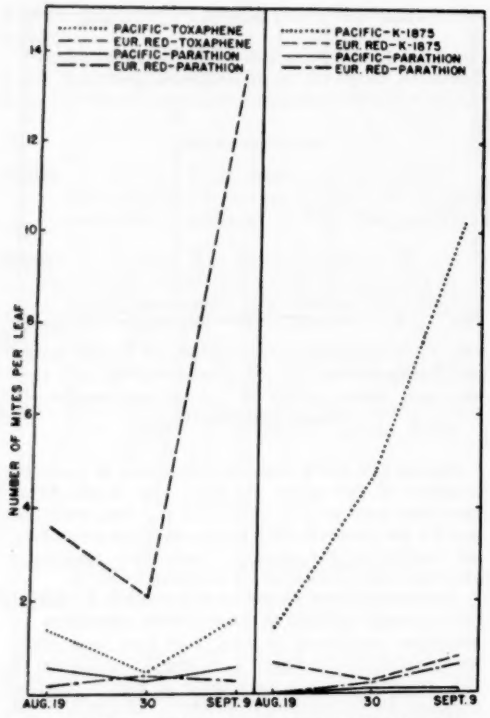

FIG. 3.—Comparative infestations of Pacific mites and European red mites. Left: in plots having three sprays of toxaphene and parathion. Right: in plots having two late sprays of bis(*p*-chlorophenoxy) methane and parathion.

not so lasting as on the Pacific mite. This chemical evidently controls the Pacific mite better than the European red mite. Parathion controls the two about equally well. If two or more applications are made, the test material controls the Pacific mite as well as parathion, and in the two-spray schedule in figure 1 control was identical.

A smaller number of tests were made with the other acaricides, and comparisons with parathion were possible, for the most part, only where two sprays had been applied.

Toxaphene, when used at 1.5 pints of 50 per cent water-miscible concentrate in the two early spray (Fig. 2, left) had a somewhat longer residual effect on the European red mite than on the Pacific mite, but when used at 1 pint in all three sprays (Fig. 3, left) the reverse was true. In neither test did toxaphene control the mites so well as parathion, although where three applications were made control of the Pacific mite was very nearly as good.

Bis(*p*-chlorophenoxy)methane, when used at 2 pounds of 40 per cent wettable powder in the two early sprays (Fig. 2, center), controlled the European red mite very much better than it did the Pacific mite. It controlled the former somewhat better than parathion did, but parathion gave better control of the latter. When used in the two late sprays (Fig. 3, right), the same thing was true except that bis(*p*-chlorophenoxy)methane did not control the European red mite any better than did parathion.

Lorol-2-thiazolinyl sulfide, when used at 1 pint of a material having 75 per cent of active ingredient in the two early sprays (Fig. 2, right), also controlled the European red mite much better than it did the Pacific mite, and even better than parathion did.

CONCLUSIONS.—Parathion controls the European red mite and the Pacific mite almost equally well. 1,1-bis(*p*-chlorophenyl)ethanol controls the Pacific mite as well as parathion if two or more applications are made, but does not control the European red mite so well. Toxaphene controls the Pacific mite almost as well as parathion, but is much less effective against the European red mite. Bis(*p*-chlorophenoxy)methane and Lorol-2-thiazolinyl sulfide, on the other hand, are fully as effective as parathion against the European red mite, but are less effective against the Pacific mite. These two materials have caused some injury to apples and pears, but the other three have not in the Pacific northwest.

Howard W. Smith, a graduate of New Hampshire University and for the past two years a fellow at Kansas State College, has accepted an assistant professorship in the Department of Entomology at Purdue University. He will take over the work of Professor B. E. Montgomery who has a year's leave for work on the ecology of the bumble bee in New Zealand under the Fulbright Act.

Richard W. Thomas, a 1949 graduate at the University of Idaho, has been appointed graduate assistant in the Department of Entomology at Purdue.

Dr. Philip Luginbill, Jr., of Lafayette, Indiana was appointed area supervisor, in the Bureau of Entomology and Plant Quarantine grasshopper control work in June, 1949, with headquarters at Madison, Wisconsin. In addition he carries on some of the control work in Michigan and northern Illinois.

Ezra Funk has returned to duty as an area supervisor on grasshopper and Mormon cricket control work in Elko, Nevada.

Frank W. Haughton who was with the Mexican Fruitfly Division, Bureau of Entomology and Plant Quarantine from 1931 to 1947, was assigned to the Division of Grasshopper Control on August 25, 1949, in Texas.

Andrew E. Frazier who has been connected continuously with the Division of Grasshopper Control, in the Bureau of Entomology and Plant Quarantine, mostly at Phoenix, Arizona since 1938, was transferred to Hannibal, Missouri on August 10, 1949. At Hannibal Mr. Frazier will be in charge of all phases of the grasshopper control program for the states of Missouri, Arkansas, Iowa and southern Illinois.

William R. Forsyth, area supervisor in charge of grasshopper control activities in the central northern Montana or Triangle Area since 1946 for the Bureau of Entomology and Plant Quarantine was transferred June 10, 1949 from Great Falls, Montana to Bismarck, North Dakota, where he assumed the same duties.

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The Need for an Annual Review of Entomology

It is now a generally accepted fact that the science of entomology has become a large complex of disciplines which range from purely taxonomic aspects to medical and basic physico-chemical orientations. The war years, especially, have accelerated this tendency toward diversification, a tendency that was inevitable and began as far back as the turn of the present century. For instance, it was only a matter of time that the entomological features of parasitology and tropical medicine would find a common meeting ground with the taxonomic and physiological store of knowledge already in the literature and it was the fusion of such originally separated fields that has given new breadth and scope to entomological problems and research. Such also was the marriage of insecticide research with preventive medicine even though one discerns a dangerous tendency today toward the submergence of basic research in favor of the immediate "returns and rewards" of applied endeavor. But this is another problem.

This growing complexity was recently emphasized at the fifty-ninth Annual Meeting of the American Association of Economic Entomologists when a petition was presented for the formation of a Section on Medical Entomology. The inclusion of this section will bring many entomologists into closer association with medical entomologists in the American Society of Tropical Medicine, the American Society of Parasitologists, the National Malaria Society, and many other organizations both domestic and foreign. This means that economic entomology takes one more step away from its original specialization and, in line with the general trend in science, tends to overlap and fuse with related fields from which it cannot now be logically divorced.

These new developments bring new problems of organization and demand a new psychology of interscientific relations. Perhaps one of the most important questions is the adequate dissemination of technical knowledge to the great body of scientists in such diverse fields as chemistry, physiology, taxonomy, disease transmission, epidemiology, etc., all of whom are bound by a common interest in problems which are essentially entomological. The natural order of response to the scientific literature is for the worker to read mainly those papers which are of more immediate importance to his own specialty. Although most entomologists must be aware of the growing interdependence of their own particular effort with that of the varied facets of entomological science there is reason to believe that the majority of workers in the field have little opportunity to become familiar with the tremendous ramifications of their science. The reasons for this situation are many, but it is here suggested that one of the major factors is to be found in the peculiar contradiction that at a time when entomology is becoming squared with more basic knowledge the literature of entomology tends to scatter more and more so that the trees of integration are obscured by a forest of specialization.

It may be argued that many entomologists do read a variety of journals and that annual meetings of special and national associations together with the more local meetings of regional groups overcome this problem. It may also be contended that the abstracting journals serve to bring the diverse knowledge of entomology within the active purview of the average scientist. Valuable as these factors may be it is here argued that what is needed is a systematic and regularly issued volume in which the entomological research of a particular time period is synthesized and correlated by workers with many years of wide experience in their chosen research. This type of publication is, of course, basically different from journals of ab-

stracts which are essentially the listing of condensed papers under a single cover and in assigned categories of knowledge. On the one hand we have individual items whose interrelationships depend upon fortuitous juxtaposition, while on the other we have a qualitative synthesis which brings to the reader both facts and interpretation. Some may still point to the *Index of American Economic Entomology* which, the writer has been informed, is now being planned as an annual publication. It would be no less than redundant to discuss the function of the *Index* which is certainly not one of critical evaluation but the simple listing of papers according to subject. Although there would not be any point of duplication between the *Index* and a volume of interpretive essays on entomological progress, nevertheless the financing of both volumes concurrently might afford certain obstacles. If one puts aside possible financial objections, however, and considers the matter on its scientific merits, it is difficult to avoid the conclusion that the science of entomology is in need of an annual review.

The institution of the annual review is already a well established medium for the exchange and dissemination of technical information in a variety of fields. Most workers are undoubtedly familiar with one or more of the annual volumes published by Annual Reviews, Inc. of Stanford, California. The well known *Annual Review of Biochemistry* reached its seventeenth volume in 1948. The *Annual Review of Physiology* is already well established and the first volume of an *Annual Review of Microbiology* was issued in 1947. In addition, the Editorial Board has indicated that the introductory volumes of annual reviews of plant physiology, psychology, physical chemistry, and medicine will be issued by 1950.

It is quite clear that these reviews make no attempt to be exhaustive and that the reviewers must scan the literature critically so that only the most significant papers are covered. The hope has been that scientists in various fields "would receive some relief through a sort of 'predigestion' process." As the editors have indicated, the reviews are intended to be critical appraisals and not mere compilations. The individual reviewer (or team of reviewers) has important standing in his field and may choose to omit even worthwhile contributions as not of moment to the cardinal thesis of the paper. Any onesidedness that may result is offset by the practice of soliciting the services of different reviewers for the same subject in succeeding years thus ensuring a varied theoretical approach. Reviews of this type answer the needs of many scientists with diverse interests in a single broad field and also supplement the more exhaustive treatments of usually more limited topics which appear in journals of the type exemplified by *Bacteriological Reviews* and *Biological Reviews*.

The publication of an *Annual Review of Entomology* is a necessity which flows from the inexorable logic of contemporary scientific growth. It is an expression of the interdependence of entomological and other scientific disciplines and a reflection of the maturing epoch of team-work in entomological research. Individual entomologists have striven for this objective in the past, but in a very real sense such a book as *Recent Advances in Entomology*, written over a decade ago by the late A. D. Imms, was an anachronism even though it stands as a landmark in entomological adumbration. But the day of the encyclopedist is past and what is needed are joint efforts in which each section is written by research workers in a particular field In 1940 Craig and Hoskins published a review of insect biochemistry and Trager published a review of insect nutrition in 1947. These papers could have been portions of a review of entomology had such a publication been in existence. Many other examples could be given.

In closing, I would like to suggest that a committee of the American Association of Economic Entomologists be formed to approach other entomological organizations and associations of parasitologists, etc , in order to discuss the possibility of publishing an annual review. Many of the private industries employing entomologists might also be contacted for financial aid since they would undoubtedly stand to gain by this venture. The participation of industrial research scientists in the writing of reviews has been demonstrated by the *Annual Review of Biochemistry*. It is to be hoped that entomologists may soon initiate the practice of an annual review in the spirit of a science that realizes its own maturity.

Proceedings of the Twenty-Third Annual Meeting
The Cotton States Branch
American Association of Economic Entomologists
L.S.U. Campus, Baton Rouge, La.
January 31, February 1 and 2, 1949

The twenty-third annual meeting of the Cotton States Branch, A.A.E.E. was held in the Agricultural Auditorium of the Louisiana State University, Baton Rouge, Louisiana on January 31, February 1 and 2, 1949. This meeting was held concurrently with the Annual Meeting of the Association of Southern Agricultural Workers. The meetings were held under adverse weather conditions, in fact, in the midst of one of the worst snow and ice storms that the South has experienced in many years. Transportation by automobile was handicapped, thereby curtailing to some extent the attendance.

The registration reached a total of 163. Although the attendance was somewhat smaller than usual, the paper reading sessions were well attended and there was unusual interest manifested throughout the meetings.

Prominent speakers appeared on the program at various intervals during the 3-day meeting and rendered tremendous contributions toward making the twenty-third annual meeting an outstanding success.

One of the highlights of the meeting came at the opening of the first afternoon session when Chairman John T. Creighton delivered a masterful address on the subject "The Future of Southern Entomology." This address was an inspiration as well as a challenge to every entomologist residing or working in the Cotton States Branch territory. It also challenged industry, legislative bodies, teachers, and other groups to meet the present entomological problems of the region.

Among the guest speakers were A. M. Boyce, *President*, C. P. Clausen, *Vice-President*, and F. N. Cory, *Secretary*, of the Parent Association; E. R. Sasscer, Division of Foreign Plant Quarantines, B.E.P.Q., Washington, D. C., and Dr. Ralph H. Allee, Director of the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica.

The annual banquet, held in the Venetian Room of the L.S.U. Cafeteria, was colorful and enjoyable. The entertainment was furnished by Pan-American students of L.S.U.

The local committee on arrangements, consisting I. J. Becnel and C. E. Smith, Co-Chairmen, R. L. Cockerham and A. L. Dugas, members, deserves much credit for performing a difficult task in a very excellent manner.

The following reports were submitted and unanimously approved.

Report of Secretary-Treasurer

A full report of the Twenty-Second annual meeting of the Cotton States Branch A.A.E.E., which was held in Atlanta, Georgia was published in the June issue of the Journal of Economic Entomology, Volume 41, Number 3, pages 532 to 534.

During the year just ended there was a gain of 25 active members and of 66 contributing members, or a total gain of 91.

Financial Report

Receipts		
Checking Account (Deposited Citizens National Bank, Waco, Tex.): Check from John T. Creighton	$371.75	
Dues collected and deposited	7.00	
Savings Account, Atlanta National Bank, Atlanta, Ga.	126.63	
Total Receipts		$505.38
Disbursements		
Stamps, envelopes and mailing permit	$ 54.41	
2 Rubber stamps	3.10	
Celluloid badges and badge tickets	18.26	
Programs (printing 1,000)	50.82	
3 Receipt books (450 Ind. receipts)	1.35	
Telephone and telegraph messages	21.18	
Total Disbursements		149.12
Balance on hand January 28, 1949		$356.26
Distributed as Follows:		
Checking Account, Citizens National Bank, Waco, Tex.	$229.63	
Savings Account, Atlanta National Bank, Atlanta, Ga.	126.63	
Total	$356.26	

Report of the Resolutions Committee

1. Whereas, the members of the Cotton States Branch of the American Association of Economic Entomologists, in attendance at the 23rd annual meeting at Baton Rouge, Louisiana on January 31, February 1 and 2, 1949 have enjoyed an interesting and profitable meeting. Therefore, Be it Resolved: That we hereby express our sincere appreciation to the following individuals, groups, and agencies who made this occasion a success.

(a) Louisiana State University and A. & M. College for their many courtesies.

(b) To Mr. I. J. Becnel and Mr. C. E. Smith, Co-chairmen, and other members of the local arrangements committee, and also to Dr. and Mrs. W. H. Gates and Mrs. Audrey C. Frances for serving coffee and donating cream.

(c) Dr. A. M. Boyce, President of the American Association of Economic Entomologists, Dr. C. P. Clausen, Vice-President, and Dr. E. N. Cory, Sec'y-Treas., for their presence here representing the National Association and their interesting and informative talks.

(d) Dr. Ralph H. Allee, Director of the Inter-American Institute of Agricultural Sciences and other guest speakers whose presence and informative talks added greatly to the success of the meeting.

(e) Mr. H. Bruce Boudreaux for his services in so ably handling the matter of projection.

(f) Our Chairman, Dr. John T. Creighton, for his splendid address and film of his Central American tour.

(g) Our Chairman, Vice-Chairman and Secretary for so ably fulfilling their duties during the meeting and in making preparations therefor.

2. The Cotton States Branch extends greetings to the Texas Entomological Society and wishes for them a most successful meeting at Waco, Texas, February 17, and 18, 1949.

J. C. Gaines
John C. Alden
P. K. Harrison

Report of the Executive Committee

The Executive Committee makes the following recommendations:

1. That the Cotton States Branch meet jointly with the parent association in Tampa, Florida on December 13 to 16, 1949 and that the following meeting be held west of the Mississippi in accordance with the previously adopted schedule of meetings.

2. That the incoming executive committee contact Professor R. W. Harned of the U. S. Bureau of Entomology and Plant Quarantine and representatives of the Cotton Council relative to combining one or more meetings which southern entomologists attend.

3. That the Cotton States Branch continue the previously adopted policy of holding meetings one year in the eastern territory, the next year in the Mississippi River territory, the third year in the western territory, and the fourth year again in the Mississippi River territory. Also, that when such a schedule coincides with the meetings of the Southern Association of Agricultural Workers that the meetings be held in conjunction with that organization, if arrangements that are satisfactory to the executive committee can be made.

4. That the American Association of Economic Entomologists endeavor to amend the present constitution to provide for continuous representation from each branch on the executive committee.

5. That the name of the Cotton States Branch be changed and that a more appropriate name be selected by the incoming Executive Committee during the year and adopted at the Tampa meetings. It is requested that the membership suggest names to the Secretary for consideration.

REPORT OF THE AUDITING COMMITTEE

Your committee has examined the bank statements, cancelled checks and receipts and have compared them with the Secretary-Treasurer's report. We find the report is correct and that the records are in good shape.

Respectfully submitted

C. F. RAINWATER S. L. CALHOUN

E. K. BYHUM, *Chairman*

REPORT OF THE AUDITING COMMITTEE

We nominate the following for officers of our Branch for the ensuing year:

Chairman—E. W. Dunnam, Stoneville, Miss.

Vice-Chairman—W. C. Nettles, Clemson, S. C.

OLIVER I. SNAPP O. W. ROSEWALL

C. E. SMITH, *Chairman*

MEMBERS AND GUESTS REGISTERED

Abadie, L. F.
Adams, J. F.
Alden, John C.
Alexander, C. C.
Allan, Paul
Allee, Ralph H.
Allen, Norman
Ames, John M.
Arant, F. S.

Baker, Thomas J.
Bailey, L. H.
Bales, I. W.
Baskin, W. H.
Beckham, C. M.
Beenel, I. J.
Betts, Paul C.
Bickerton, Jack M.
Bixby, Arthur F.
B ndy, Floyd F.
B th, R. J.
Boudreaux, H. Bruce
Boyce, A. M.
Brooks, James W.
Brubaker, Ross W.
Budd, M. R.
Burnside, W. H.
Bussart, J. Everett
Bynum, E. K.

Calhoun, S. L.
Cancienne, E. A.
Cassidy, T. P.
Chamberlin, F. S.
Chandler, S. C.
Clausen, C. P.
Cochran, James H.
Cochran, R. N.
Cockerham, K. L.
Compton, C. C.
Connelly, Albert B.
Cory, Ernest N.
Coyne, John F.
Creighton, John T.
Crigler, J. L.
Crawford, S., Jr.
Criswell, Jack F.
Crutchfield, Cecil M.
Catchings, Thomas F.

Deputy, O. D.
Dillard, W. T.
Dorland, Wayne
Douglas, W. A.
Dugas, A. L.
Dunnam, E. W.
Dupree, Minter
Dutsch, Thomas P.
Dye, H. W.

Eden, W. G.
Ewing, K. P.

Floyd, E. H.

Gaines, J. C.
Galloway, A. L.
Glover, Leon C.
Grazar, A. E.
Griffiths, J. T.

Hamman, Robert E.
Hansberry, Roy
Harrison, P. K.
Hatcher, R. F.
Henley, Felix T.
Herr, F. W.
Hersfall, J. L.
Hetrick, L. A.

Iglinsky, William
Ingram, J. W.
Ivy, E. E.

Johnson, Arnold N.
Johnson, Harper S., Jr.
Johnston, H. R.

Kenaga, Eugene
King, Chas. A., Jr.
King, Charles
Kowal, R. Joseph
Krieger, George
Kilpatrick, John W.

Landrum, John M.
Lee, Horace W.
Lee, J. H.
Leeanard, G. F.
Lett, Edwin
Lloyd, Ralph R., Jr.

McCreight, Warren T.
McCrory, S. J.
McDuffie, William C.
Mank, L. M.
Marlow, W. L.
Meadows, C. M.
Meek, Roy C.
Millender, H. C.
Miller, C. E.
Miller, K. E.
Mistric, Walter J., Jr.
Monroe, L. A.
Moreland, James H.
Morris, Ralph L.
Muller, George F.
Murphy, C. E.

Naylor, Mace
Newsom, L. D.
Nikitin, A. A.
Normand, W. C.

O'Brien, James H.
Otwell, Orel G.

Parencia, C. R.
Peterson, P. D.
Petrey, Bill
Petrus, A.
Pierce, W. C.
Pierce, Henry F.
Piesbergen, N.
Plowden, John
Purswell, H. D.

Rainwater, C. F.
Rapp, F. V.
Reed, T. Walter
Rene, P. J.
Rives, Q. L.
Roberts, J. Harvey
Rogers, Andrew J.
Rosewall, O. W.
Rowe, W. Mercer, Jr.

Sanders, John M.
Sanders, J. G.
Sasscer, E. R.
Secrest, Herbert C.
Sharp, S. S.
Siddall, Cameron
Smith, C. E.
Smith, Willis R.
Snapp, Oliver I.
Spicer, William J.
Steinhauer, C. J.
Stevens, John C.
Strong, Rudolph G.

Thomas, Truman
Torrey, John W.
Trigg, R. L.
Tresclair, J. M.
Turner, Frank

Watson, R. C.
Weed, Alfred
Wene, George
White, J. F.
Whitehead, W. C.
Whitfield, D. A.
Wilbanks, Roger
Williams, X. X.
Wilson, C. A.
Wood, J. R.
Wood, H. J.
Wood, Gordon R.
Woodbury, E. N.

Yates, R. T.
Young, David F., Jr.
Young, B. J.

PROCEEDINGS OF THE FOURTH ANNUAL MEETING NORTH CENTRAL STATES BRANCH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

HOTEL SCHROEDER, MILWAUKEE, WIS. March 24–25, 1949

The fourth annual meeting of the North Central States Branch, A.A.E.E. was held at Milwaukee, Wisconsin on March 24 and 25, 1949.

Officers during this meeting were Frank N. Wallace, President; Wm. G. Bradley, Vice-President; and J. W. Apple, Secretary-Treasurer.

The committee on local arrangements consisted of E. L. Chambers—Chairman, T. C. Allen, C. L. Fluke, C. B. Eaton, and H. N. Putnam.

The program was arranged by T. L. Aamodt—Chairman. L. F. Steiner, and R. L. Janes.

Some 116 topics were listed for presentation during the two-day session. Topics dealing with experimental results from the use of the newer insecticides occupied a prominent place on the program. The following sectional meetings were held during half day or evening periods:

Insecticides, Residues and Equipment—G. C. Decker, *Chairman*
Field Crop Insects—P. O. Ritcher, *Chairman*
Forest Entomology—R. D. Shenefelt & A. C. Hodson, *Chairmen*
Man and Animal Insects—Ephriam Hixson, *Chairman*
Extension Entomology—E. H. Fisher & R. L. Janes, *Chairmen*
Apiculture—C. L. Farrar & F. B. Paddock, *Chairmen*
Truck Crop Insects—A. A. Granovsky, *Chairman*
Fruit Insects—Ray Hutson & L. F. Steiner, *Chairmen*

One topic not listed in the program but arranged for at the last minute was a talk by M. R. Stephens of the Chicago office of the Pure Food and Drug Administration. Mr. Stephens presented the current attitude of P. F. & D. in regard to the contamination of food with insecticides, with particular emphasis on DDT.

FIRST BUSINESS SESSION

THURSDAY MARCH 24, 1949

President Wallace appointed the following committees for the 1949 meeting:

Resolutions: H. GUNDERSON, *Chairman*, J. J. DAVIS, M. SCHLOSBERG.
Auditing: C. W. KEARNS, P. O. RITCHER.
Time and Place of 1950 Meeting: E. HIXSON, *Chairman*, J. H. LILLY, A. W. BUZICKY.

The Nominating Committee was called upon to present their selection of nominees for new officers in the Branch. R. C. Smith, chairman of this Committee, proposed the following names:

For President: G. M. LIST, W. A. PRICE.
For Vice-President: R. HUTSON, J. A. MUNRO.
For Secretary-Treasurer: J. W. APPLE, L. JENKINS.

This report of the Nominating Committee was approved by the membership.

President Wallace called for nominations from the floor. No other nominations were made before nominations were closed. Ballots were marked by the members and then collected by the Nominating Committee for tallying.

President Wallace called for nominations for the new Nominating Committee. C. H. Richardson, J. H. Bigger and T. L. Aamodt were nominated, whereupon the nominations were closed. Even though only three nominees were proposed for the three man committee, it was necessary (according to the Constitution) for the members to vote by written ballot for these three men. The old Nominating Committee was appointed by President Wallace to tally the ballots.

President Wallace called on A. M. Boyce, President of the American Association of Economic Entomologists, to speak in behalf of the parent Association.

Dr. Boyce brought greetings from the American Association and urged all entomologists to attend the next annual meeting at Tampa, Florida next December 13–16. Dr. Boyce assured the listeners that it would be one of the finest meetings the Association has ever held.

President Wallace called on Clay Lyle to review the actions taken by the Special Committee of the A.A.E.E. on the Welfare of Entomology in Relation to the Hoover Report.

Dr. Lyle stated that the committee has requested the Secretary of Agriculture to give serious consideration to the matter before decentralizing the entomological work of the Department.

The 1949 banquet of the North Central States Branch held during the evening of March 24 was considered by many to be the most successful banquet in the history of the organization. The excellent dinner served by the Hotel Schroeder was supplemented by cranberries from the Wisconsin Cranberry Growers, cheese from the Wisconsin Department of Agriculture, and honey candy from Honey Acres. The Milwaukee Florists Association provided roses for each dinner table. Twenty-four insecticide and equipment manufacturers made it possible to have an orchestra and a vaudeville team to entertain the group.

Following the banquet, Dr. A. M. Boyce made a short address on the virtues of Florida, since the next annual meeting of the American Association is to be held in that state. This was hard for a Californian to do, but Dr. Boyce meant every word he said.

Dr. H. B. Mills, Chief of the Illinois Natural History Survey, delivered the banquet address. Dr. Mills gave a very interesting talk on the subject "Eaters and the Eaten." This talk had been prepared for the banquet at the national meetings in December, but due to bad flying weather Dr. Mills was unable to reach New York. It was indeed fortunate for the Branch that Dr. Mills agreed to give his talk before our group.

SECOND BUSINESS SESSION
FRIDAY MARCH 25, 1949

President Wallace called for the following reports

TREASURER'S REPORT

Credits		
Balance in Treasury, March..	$316.60	
230 copies of 1948 Proceedings @$2.00	460.00	
Balance during 1948 Registration	10.25	
Bank Interest	4.01	
Received from Am. Assoc. Econ. Ent. (For 1948 meeting expenses)	78.45	
Total	$869.31	$869.31
Debits		
Expenses of 1948 Meeting	$ 78.45	
Paid to U. S. Post Office (Envelopes—Cards—Money orders)	9.78	
Paid to U. of Ill. (Mimeographing and mailing)	41.16	
Telegrams (Howard and Osborn)	1.62	
Cost of Preparing 1948 Proceedings	265.79	
Payment to Recorder	25.00	
Stenographic Service	37.00	
Office Supplies	24.57	
Badges for 1949 Meeting	19.38	
Programs for 1949 Meeting	35.00	
Total	$537.75	$537.75
		$331.56

J. W. APPLE, *Secretary-Treasurer*

REPORT OF AUDITING COMMITTEE

Treasurer's report examined and found correct, March 25, 1949.

C. W. KEARNS
PAUL O. RITCHER

Report accepted by membership.

REPORT OF COMMITTEE ON TIME AND PLACE OF NEXT MEETING

Your committee on the place for meeting in 1950 has selected Kansas City, Mo.

The time of meeting to be the usual time in March, the Executive Committee is to select the exact dates and notify the membership.

EPHRIAM HIXSON, *Chairman*
A. W. BUZICKY
J. H. LILLY

Report accepted by membership.

REPORT OF RESOLUTIONS COMMITTEE

Resolution No. 1

WHEREAS: the North Central States Branch of the American Association of Economic Entomologists has successfully completed its fourth annual meeting, therefore

Be it Resolved: that this group express its appreciation to the Program Committee for the timely discussion topics; to the speakers who gave of their time and experience to present the subjects; to the Committee on Local Arrangements for the smooth operation of arrangements and facilities; to the commercial companies who provided the entertainment at the banquet; to the management and employees of the Hotel Schroeder for their courtesy and prompt service; and to the Milwaukee Chamber of Commerce for their aid and wholehearted cooperation.

Resolution No. 2

WHEREAS: the profession of entomology generally, and the North Central States Branch in particular have lost two of the entomological pioneers in this country, C. L. Metcalf of Illinois, and E. G. Kelly of Kansas, therefore

Be it Resolved: that the Secretary of the North Central States Branch of the AAEE extend to the families of Dr. Metcalf and Dr. Kelly our sympathies and condolences in their loss.

Resolution No. 3

WHEREAS: most recommendations for field crop insect control are given as pounds of active or actual insecticide per acre and most insecticide labels are not specific as to content, therefore,

Be it Resolved: that this branch urge formulators and processors to place on the label the pounds of active ingredient in the package.

Resolution No. 4

WHEREAS: there is great confusion as to safe use of the newer insecticides and the fate of residues present on plants, animals and inanimate surfaces, and great uncertainty as to interpretation of analytical tests, therefore

Be it Resolved: that the North Central States Branch of the American Association of Economic Entomologists urge that there be close correlation between the Bureau of Entomology and Plant Quarantine, the States, other agencies possessing research data, and the Food and Drug Administration so that the results of research can be applied in *making* rulings, thus decreasing confusion, reducing hardship among producers and processors to a minimum and preventing hasty and unwarranted rulings.

Resolution No. 5

WHEREAS: the meetings of the North Central States entomologists have always been characterized by informal discussions in which everyone participated, and whereas it appears that this informality is endangered by overcrowding the program, thus restricting discussion and preventing the valuable free interchange of ideas, therefore

Be it Resolved: that the program committee in the future consider the following recommended procedure:

A. Start planning the next year's program as soon as possible following the annual meeting.
B. Circularize the membership for suggestions before Oct. 1st each year.
C. Make up a tentative program consisting of broad topics, and list for each subject a number of possible discussion *leaders*.
D. Select subjects that are controversial and that require exchange of views before decisions can be made.
E. Notify each discussion leader of his topic by

January 15, so he can make plans for the discussion, including properly prepared, easily-seen visual aids and can notify others whom he wishes to have prepare notes on specific phases.

F. Each discussion leader or section chairman will thus be made responsible for the timing of his program and can encourage open, free and complete discussion of those phases of the program which are shown to be most interesting to the group.

Resolution No. 6

WHEREAS: the newer chlorinated hydrocarbons now being used as insecticides have great publicity value, and have been the subject of distorted, ill-advised, inaccurate articles in newspapers, popular and scientific magazines and journals, and have been unjustly and indiscriminately blamed as the cause of livestock and wildlife losses, therefore

Be it Resolved: that the North Central States Branch of the American Association of Economic Entomologists urge its members to counteract erroneous articles with publicity which is correct, and where distorted claims are proved false, to give equal publicity to the true cause of the difficulty

Resolution No. 7

WHEREAS: new chemicals with insecticidal possibilities are appearing rapidly, many of which may be released prematurely,

Be it Resolved: that entomologists, manufacturers, formulators and processors use extreme caution in promoting, releasing and or recommending new insecticides for general use. This should be done only after careful, thorough experimental work on effectiveness, toxicity to man, animals and plants, and relationship to other insecticides.

Resolution No. 8

WHEREAS: the proposed reorganization of the U. S. Department of Agriculture, based on the Hoover report, may decentralize the administration of the many phases of research, control, and quarantine activities to the serious detriment of the progress of entomology and agriculture in general, therefore

Be it Resolved: that the North Central States Branch of the AAEE endorse the action taken by the Special Committee on the Welfare of Entomology in Relation to the Hoover Report of the American Association of Economic Entomologists and respectfully calls the attention of the Secretary of Agriculture to this endorsement.

HAROLD GUNDERSON, *Chairman*
MORRIS SCHLOSBERG
J. J. DAVIS

Report accepted by membership after several corrections.

President Wallace appointed R. T. Everly of Purdue University to serve as recorder for the year of 1949.

Dr. G. C. Decker voiced the opinion that the Branch should pay the expenses of the Secretary-Treasurer to attend the present and all future annual meetings of the organization. Dr. Decker made a motion to this effect, it was seconded and approved unanimously by the membership.

Dr. Roger Smith announced the results of the election for the new nominating committee as follows: C. H. RICHARDSON, J. H. BIGGER, T. L. AAMODT

Dr. Smith as chairman of the Tally Committee reported that G. M. List received a majority of votes for President, Ray Hutson received a majority of votes for Vice-President, and J. W. Apple received a majority of votes for Secretary-Treasurer.

Since President-Elect List was not present, President Wallace asked J. J. Davis and Roger Smith to escort Vice-President-Elect Hutson to the rostrum to take over the direction of the Branch.[1]

[1] Proceedings of the Fourth Annual meeting can be obtained for $2.00 from J. W. Apple, Dept. of Entomology, Univ. of Wisconsin, Madison, Wisconsin.

THE FOLLOWING PERSONS REGISTERED DURING THE MEETING

Colorado

J. L. Hoerner
W. E. McCauley
B. T. Snipes

Illinois

E. D. Anderson
G. Bender
A. W. Bevernick
J. H. Bigger
G. H. Blake Jr.
J. F. Brandenburg
D. G. Brower
W. N. Bruce
J. E. Bussart
N. B. Carson
S. C. Chandler
C. C. Compton
M. D. Couch
S. J. Coyne
G. C. Decker
W. K. Delaplane
M. J. Drake
N. Earle
H. J. Eavis
W. A. Eichler
L. L. English
H. E. Fernando
G. S. Fraenkel
F. E. Guthrie
W. P. Hayes
W. R. Horsfall
C. W. Kearns
F. Klock
L. A. Koritz
G. A. Meisinger
H. B. Mills
A. P. Morris
D. J. Murphy
E. P. Ordas
J. H. Paullus
H. B. Petty
L. Pohly
G. Printy
J. F. Rawlings
C. C. Roan
F. J. Ronan
A. Schor
H. H. Slawson
J. Sternburg
C. R. Stull
R. Thomas
J. Warner
C. J. Weinman
C. E. White
C. R. Winter
J. M. Wright

Indiana

G. J. Baker
J. F. Benham
F. E. Bohman, Jr.
I. C. Brooks
J. A. Clark
J. J. Davis
H. O. Deay
R. T. Everly
J. E. Fahey
G. E. Gould
M. T. Grady
P. E. Hannah
K. K. Krausche
G. E. Marshall
H. McAlister
J. V. Osmun
E. Roth
M. Schlosberg
D. Schuder
L. F. Steiner
E. L. Thomas
A. W. Trippel
F. N. Wallace
P. T. Ulman
A. M. Vance
E. V. Walter
V. Walter
W. Weber
M. C. Wilson

Iowa

W. W. Abramitis
C. C. Blickenstaff
B. O. Brayton
H. L. Chada
M. H. Farrier
W. D. Fronk
H. Gunderson
V. S. Hagen
H. M. Harris
H. E. Jaques
K. H. Jarvis
J. H. Lilly
W. C. Mitchell
E. Raun
C. H. Richardson
R. Scott
L. H. Shropshire

Kansas

F. D. Butcher
P. A. Dahm

N. M. Dennis
W. T. Emery
J. C. Frankenfeld
H. B. Hungerford
J. W. Kennedy
J. B. Kring
C. D. Michener
G. L. McCall
L. M. Redlinger
T. P. Singh Teotia
H. W. Smith
R. C. Smith
E. Viale

Kentucky

W. A. Price
W. C. Rhoades
P. O. Ritcher
R. G. Tilson

Michigan

C. E. Brian
Zia Ud Deen
C. E. Dieter
F. Fletcher
R. L. Gallun
C. F. Gerlach
L. W. Gopp
S. A. Graham
A. Hastings
R. Hutson
R. L. Janes
H. King
L. E. Mills
W. F. Morofsky
F. Sherman III
H. C. Wohlers
M. Wolf

Minnesota

T. L. Aamodt
A. M. Adnestad
M. Ali
J. M. Butcher
A. W. Buzicky
F. J. Dexheimer
M. H. Doner
R. E. Erickson
D. G. Fletcher
W. G. Foard
A. A. Granovsky
P. H. Harden
H. H. Harris
F. G. Holdaway
D. R. Johnson
W. H. Kircher
J. S. McCartney
J. McConnon
C. E. Mickel
H. L. Parten

Missouri

L. E. Adams
R. V. Cree
R. L. Cuff
Mrs. R. L. Cuff
L. S. DeAtley
S. Evans
E. Hyry
L. Jenkins
G. D. Jones
R. E. Lubbehusen
J. M. Magner
R. W. Portman
P. C. Stone
G. W. Thomas
R. I. Wakeman
H. Zuhl

Nebraska

R. Fuxa
R. E. Hill
E. Hixson
J. W. Lomax
M. H. Muma
R. J. Walstrom

North Dakota

M. A. Leraas
J. A. Munro
R. L. Post
D. A. Williams

Ohio

B. A. App
K. D. Arbuthnot
W. G. Bradley
H. A. Crandell
R. H. Davidson
F. F. Dicke
M. G. Farleman
H. L. Moreland
C. R. Neiswander
R. B. Neiswander
T. H. Parks
J. B. Polivka
R. W. Rings
J. G. Rodriquez

South Dakota

C. Severin

Wisconsin

T. C. Allen
J. W. Apple
E. C. Baillie
S. Beck
D. M. Benjamin
J. W. Brooks
T. E. Bronson
M. J. Buss
E. D. Canaga
C. R. Carlson
T. R. Chamberlin
E. L. Chambers
R. K. Chapman
T. Clavadatscher
A. Cummer
T. Davich
R. J. Dicke
J. R. Dogger
J. E. Dudley
C. B. Eaton
C. L. Farrar
W. C. Ferguson
E. H. Fisher
B. C. Fluke
C. L. Fluke
A. J. Guequierre
W. Haberman
H. E. Halliday
F. Hennig
A. O. Jensen
G. S. Kido
C. B. Melander
J. T. Medler
M. E. Mercer
J. E. Naylor
J. J. Paul
L. A. Penn
R. D. Shenefelt
P. Smith
P. Stone
H. E. Thompson
W. Turrie
A. A. Whipp
R. A. Wiethaup

New York

O. H. Ellis
J. F. Adams
W. K. Feustel
B. D. Gleissner
L. G. Mayne
J. L. Poland
A. Robinson
J. G. Sanders
E. M. Searls
H. L. Straube

Washington D. C.

W. A. Baker
H. J. Grady
A. S. Hoyt
M. P. Jones
E. F. Knipling
E. L. Leclerg

Pennsylvania

A. F. Bixby
G. A. Brandes
H. G. Guy
L. M. Mank
A. C. Miller
H. G. Walker

Delaware

R. Akkerman
W. W. Fassig
J. V. Miller

New Jersey

C. C. Alexander
T. W. Reed

Oklahoma

D. Ashdown
R. R. Walton

California

A. M. Boyce

Texas

E. W. Laake

New Hampshire

M. D. Farrar

Mississippi

C. Lyle

Maryland

F. W. Poos
J. W. Apple, Sec'y.-Treas.

PROCEEDINGS OF THE THIRTY-THIRD ANNUAL MEETING PACIFIC SLOPE BRANCH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS July 16, 17 and 18, 1949

The thirty-third Annual Meeting of the Pacific Slope Branch was held at Grand Canyon, Arizona, July 16, 17, and 18, 1949. This was the first attempt to hold a meeting in a National Park, and from every viewpoint it was highly successful. Those in attendance enjoyed an excellent meeting with fine addresses and papers, and had opportunities to enjoy at the same time the beautiful scenery of the National Forest and the wonderful views of the Grand Canyon.

There was an informal get-together Wednesday evening, June 15, and a dinner Thursday night, followed by a dance, and entertainment by a cowboy orchestra. Sightseeing tours and a special luncheon were arranged for the ladies.

The regular program consisted of 59 papers, including several informal talks, and some very fine invitational papers.

The meeting was opened with an address of welcome by Dr. Harold C. Bryant, Supt. of Grand

Canyon National Park, and a response by Chairman James Roney. This was followed by some informal remarks by President Boyce and Vice President Clausen

The Secretary-Treasurer's reports were presented and committees appointed at the preliminary business session. At the final business session, committee reports were discussed and accepted.

REPORT OF THE SECRETARY 1948–1949

The Pacific Slope Branch has existed for 33 years without a constitution or by-laws. This informal organization has been very successful, but it now seems desirable to have a more formal organization.

We now have over 600 members, and attendance at our annual meetings exceeds 300. The responsibilities of carrying on the affairs of our Branch, and especially arrangements for the annual meetings, are becoming too great for our yearly elected officers. We should consider having an executive committee to assume these responsibilities, with members elected in rotation for 3-year terms.

We have always considered that our territory included the eleven western states, together with Hawaii and British Columbia. We have called ourselves the Pacific Slope Branch, in spite of the fact that part of Montana, Wyoming, Colorado, and New Mexico are East of the Continental Divide. Perhaps we might choose a more appropriate name such as the Western Branch. The Texas Entomological Society is considering the possibility of becoming the Southwestern Branch, and may include New Mexico.

In view of these facts, I wish to make the following recommendation: (1) That the incoming President appoint a representative committee of at least seven members to consider the following:

a. A brief constitution and by-laws
b. The territorial limits of our Branch
c. Whether our name should be changed or not
d. The desirability of having an executive committee.

It is suggested that this committee consider these matters and any others they think pertinent; make definite recommendations for such action as they deem desirable; and report their findings at our next meeting in 1950.

Respectfully submitted,
ROY E. CAMPBELL, *Secretary*

TREASURER'S REPORT 1948–1949

		Credits	*Paid Out*
Balance in bank, June 6, 1948		$438.42	
June 7, 1948	Litho Press for multilithing		$ 6.51
June 14, 1948	E. J. Newcomer (Pres. Miscl. Expense)		4.80
June 16, 1948	Rent of rooms for Vancouver meeting		150.00
June 17, 1948	Young (printing programs)		78.87
Nov. 11, 1948	Bal. from Vancouver meeting	385.31	
Nov. 19, 1948	Cash for Postage and Registered pkgs.		3.26
Apr. 12, 1949	Postage for notices of meeting in June		18.00
Apr. 15, 1949	Postage for notices of meeting in June		21.60
May 3, 1949	Multilithing notices of June meeting		87.87
June 7, 1949	Cash for telephone calls and telegram		3.16
			374.07 Paid Out
Balance in bank, June 8, 1949			449.66 Balance
		$823.73	$823.73

ROY E. CAMPBELL,
Treasurer

Treasurer's accounts audited and approved, June 18, 1919.

K. E. MAXWELL
W. H. STEVENSON
WALTER EBELING, *Chairman*, Auditing Committee

REPORT OF PLACE-OF-MEETING COMMITTEE

The committee recommends that the selection of a place for the 1950 meeting be postponed for the present. A thorough survey will be made and a place selected within 3 months.

The committee further recommends that an interim committee be appointed to investigate the setting up of a 3- to 5-year schedule of meeting places, and report on it at our next meeting.

Place-of-Meeting Committee,
G. F. KNOWLTON — ED. LITTOOY, *Chairman*
A. W. LINGQUIST — H. M. ARMITAGE
O. B. HITCHCOCK

REPORT OF RESOLUTIONS COMMITTEE

1. Whereas the deaths of C. T. Vorhies, W. B. Herms, and A. O. Larson have left us with deep feelings of loss, be it resolved that we express, through our Secretary, our regrets and sympathy to the families of these deceased members.

2. Be it hereby resolved that our Secretary be instructed to extend our appreciation to the various committees, invitational speakers, and the several who have made this meeting so enjoyable and successful: particularly to Dr. H. C. Bryant and his associates of the National Park Service; to Mr. Walter D. Rouser of the Fred Harvey System; to Mr. M. F. Wharton for making the local arrangements for the meeting; to Mrs. J. Allen White and her committee for the most enjoyable entertainment for the ladies; and to Mr. Ed. Coe for his faithful operation of the public address system.

3. Be it hereby resolved that the State of Arizona, through its Extension Entomologist, J. N. Roney, continue to maintain the Grand Canyon for future meetings of the Pacific Slope Branch, A.A.E.E., their heirs and assigns, forever!

Resolutions Committee
A. F. KIRKPATRICK
J. R. EYER
CHAS. H. MARTIN, *Chairman*

REPORT OF THE NOMINATING COMMITTEE

Officers for 1949–1950

Chairman.....H. M. ARMITAGE
Vice Chairman.....ED. LITTOOY
Secretary-Treasurer.....ROY E. CAMPBELL

Nominating Committee
A. J. FLEBUT, *Chairman*
R. L. METCALF
DON C. MOTE

OBITUARIES

Andrew Delmar Hopkins—1857-1948

No one phrase can better express the character and accomplishments of Andrew Delmar Hopkins than to say that he was the pioneer of forest entomology in America. If we look back to the period when American forestry was in its genesis, we find that Hopkins had more to do with the recognition of entomology as an essential phase of protection of our national forest resources than any other man of his time. Soon after the National Forests were established, those concerned with their administration and protection began to take cognizance of the inroads of insects upon potential timber supply. Bark-beetle infestations in the Black Hills of South

ANDREW DELMAR HOPKINS IN 1894

Dakota, defoliators in the fir stands of the Northwest, and the spruce budworm in the Northeast were then destroying millions of board feet of potential lumber. But little was known about these insects, their identity, or what could be done to keep their depredations under control. It was at this time, in 1902, that Dr. A. D. Hopkins became the first Chief of the Division of Forest Insect Investigations of what was then the Bureau of Entomology of the U. S. Department of Agriculture. He had been associated with Federal work before this, however, on special assignments in 1899, 1900, and in 1901.

Hopkins brought to these assignments a forceful, energetic personality, a keen sense of biological values, and a background of more than a decade of contact with forest insect problems while he was with the West Virginia Agricultural Experiment Station. His task was a formidable one. There were few guideposts to the field which included all of the widely diversified forest types of the continent and their insect enemies. Many of the most important insect species were then undescribed; their biology and distribution were unknown. Exploration, fact-finding, and interpretation of what could be learned became the first objectives of the work that Dr. Hopkins directed over a period of 22 years. This was a type of work for which he had an unlimited enthusiasm that was contagious among the men he selected to work with him. During these years a vast amount of information was assembled, and the small group of men who made up the Division of Forest Insect Investigations produced publications covering many aspects of the various problems. These included studies on the classification, biology, habits, distribution, and responses to environment of many groups of insect pests of forests. These publications and the work on which they were based have served as the foundation upon which forest entomology has built most of its later expansion. Hopkins' individual contribution, Departmental Bulletin No. 83, "The Genus Dendroctonus" is still one of the classics in the literature of forest entomology. Others of the 175 titles included in his bibliography are still consulted and frequently quoted.

Andrew Delmar Hopkins was born August 20, 1857, on a farm at Evans, near Ripley, Jackson County, West Virginia. His early work in entomology was with insects near at hand. The manuscript, with original drawings, on the raspberry borer, its habits, parasites, and damage which he prepared from studies made on his farm was published by the West Virginia Agricultural Experiment Station. In 1890 he was employed as a special agent of that Station and in 1891 became the State Entomologist. He continued with the West Virginia Station until 1902 when he resigned to accept a position in the Federal entomological service to head up investigations on forest insects and organize what shortly later became the Division of Forest Insects. In 1892 he went to Germany to search for natural enemies that might aid in controlling the southern bark beetle, *Dendroctonus frontalis* Zimm. He successfully introduced the predaceous *Clerus formicarius* Linn. In recognition of this and other work, he was honored with the degree Doctor of Philosophy in 1893. He was a member of several scientific societies, especially those in the field of biology and meteorology. In 1902 he was President of the American Association of Economic Entomologists, and in 1907 and 1908 he was President of the Entomological Society of Washington. Although he was bedridden for nearly two years before his death on September 22, 1948, his memory and faculties were unimpaired. A short time before his death he recognized with pleasure W. S. Fisher and H. S. Barber when they, together with W. H. Anderson, visited him at his home in Parkersburg, West Virginia.

Dr. Hopkins' personality was a type that made a lasting impact on all who came in contact with him. He was a big man, physically active, with features

strikingly similar to those of William Jennings Bryan, the silver-tongued orator of that time, for whom he was frequently mistaken in his travels. In his relations with others, Hopkins was always strong in his loyalties, aggressive in his dislikes, but generous with those he worked with in harmony. Those who spent any time with Dr. Hopkins in the field were impressed by the almost uncanny intuition with which he collected insects and information of first importance to forest insect problems. He early aggressively claimed that insects killed more timber than forest fires. He strove to develop methods of control that could be used to prevent such destruction, and proposed several principles such as that of percentage control, host selection, silvicultural and management practices as aids to attain the objective.

There is additional information on A. D. Hopkins and the important contributions he made to forest entomology in an article entitled "The Progress of Forest Entomology in the United States" in the JOURNAL OF ECONOMIC ENTOMOLOGY, Vol. 16, No. 5, Oct. 1923, pp. 413–420. A photograph taken in 1894 showing him at the outset of his career is included.

T. E. SNYDER
J. M. MILLER

John B. Hull—1906-1949

John B. Hull was born in Louisville, Mississippi, September 20, 1906, and was graduated from Mississippi State College, formerly known as Mississippi Agricultural and Mechanical College, in January, 1930.

During the same year he reported for duty with the Bureau of Entomology and Plant Quarantine in Charleston, South Carolina. Using a flotation method with samples of marsh soil, he assisted in determining the principal breeding places of *Culicoides canithorax* in salt marshes. Because smaller sand flies were more numerous along the littoral of Florida and represented a different and important problem, Mr. Hull set up a field station at Fort Pierce, Florida, and made special studies on the breeding places of *Culicoides furens*. After determining the breeding places of this pest in mangrove marshes, he cooperated with local authorities and demonstrated a practical drainage method for control of both sand flies and salt-marsh mosquitoes. His work was interrupted by war service as a lieutenant, j.g., in the United States Navy. Upon his return he was employed by the Saint Lucie Sanitary District, and was able to put into operation an adequate method for preventing the breeding of sand flies and salt-marsh mosquitoes. Mr. Hull was serving as superintendent of this successful project at the time of his death on June 10, 1949.

On November 4, 1933, Mr. Hull was married to Sarah Teter, and the union was blessed with one son, John B. Hull, Jr. He is survived by his wife and son, who live at Fort Pierce, Florida.

Mr. Hull made friends wherever he worked, and was best known for hard work and for obtaining practical results on a difficult problem. He was rather strong in his likes and dislikes, but it was seldom that anyone could find an error in his judgment. Although a young man, he served as a consultant to different areas in need of sand-fly and mosquito control, sometimes outside of the continental United States. In different subtropical areas his recommendations have served as a basis for controlling these pests. He had the ability to sell the results of his work, to lay out an efficient project, to supervise the use of labor, and to conduct a timely program for protection of areas from sand flies and salt-marsh mosquitoes. It is seldom that one encounters a technical man with such a practical turn of mind, and his untimely death results in a distinct loss to all who knew him.

W. E. DOVE

PROFESSOR J. M. ROBINSON DIES

Professor James Mathews Robinson, for the past thirty years a member of the staff of the Alabama Polytechnic Institute, died suddenly of a heart attack on August 27, 1949. An obituary has been prepared by Dr. F. S. Arant and Professor F. E. Guyton and will be published in the December number of the JOURNAL.

CLASSIFIED

Advertisements of commodities for sale or exchange or of services will be entered at 50 cents per issue or $2.50 per year. Advertisements requesting information for use in publications will be charged at the rate of $1 per advertisement to run as long as space permits. Send notices and cash in advance to Ernest N. Cory, College Park, Md., by the 15th of the month preceding publication.

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FOR SALE: "Unbidden House Guests," an Ecology of the House, by Hugo Hartnack. Vol. 1, Containing Parts (1) General; Part (2) Plants as housepests; Part (3) Lower animals including arthropods. Part (5) Chordata. Bound, 560 pages. 450 Illustrations. Shipping Weight 4 pounds. Price in U.S.: $12.00 plus postage. Ask for Collection of Reviews and folder. Hartnack Publishing Company, 324 N. 4th Street, Tacoma 3, Washington.

PLANT PATHOLOGIST: For laboratory and field research with fungicides. Background in physiology and/or biochemistry desirable. Experience necessary. Requires some travel. Salary open. Box II, College Park, Maryland

ENTOMOLOGIST WANTED: To head service department of large pest control firm with home office in Pittsburgh and branches in several cities. Candidate should have several years of field experience and preferably Ph.D. Duties would include handling sizeable staff of service men, training new men for pest control work, supervising insecticide formulations. This is a "big" job with unlimited possibilities. There is available a nice five-room, two bedroom apartment at very reasonable rental. Submit complete data on training, experience, salary requirements and photo. Strictly confidential. Address: Mr. L. L. Crosby, President, Commonwealth Sanitation Co., 3567 Bigelow Blvd., Pittsburgh 13, Pa.

FOR SALE—Two-striped walking stick, *Anisomorpha buprestoides* (Stoll) expertly preserved for classroom dissection. Adult ♀'s three inches long and stout bodied. Internal structures show clearly even without magnification. Unsurpassed for training students in Zoology or Entomology. L. A. Hetrick, 1836 N. 8th St., Gainesville, Florida.

ECONOMIC ENTOMOLOGIST. Ph.D., 1948. Formerly Assistant Professor State University. Desires position with greater opportunity for advancement. Teaching and research preferred. Experience in teaching economic entomology, insecticide chemistry, etc. Research experience in field and laboratory. Reply to Box B, Journal of Economic Entomology, College Park, Maryland.

FOR SALE: Monograph of the Culicidae, by F. V. Theobald. Six volumes, I to V, with volume of plates, 1901 to 1910, bound, $30.00. Also complete set of "Revista de Entomologia," Vols. 1 to 19, 1931 to 1948, edited by Thos. Borgmeier, Rio de Janeiro, and containing much original work on neotropical insects. $100.00. W. H. W. Komp, 6906 Dartmouth Ave., College Park, Maryland, U.S.A.